

Organic Chemistry Part 2

CHAPTER 9

Biomolecules

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9

Biomolecules

9.1 INTRODUCTION

Biomolecules are common to living systems. These constitute carbohydrates, proteins, enzymes, lipids, vitamins, hormones, and nucleic acids. Some compounds for storage and exchange of energy like adenosine triphosphate (ATP) and some polymers like synthetic polymers also fall in this category; for example, starch, proteins, and nucleic acids are the condensation polymers of simple sugars, amino acids, and nucleotides, respectively. Majority of the biochemical reactions occur in dilute solutions (pH~7) at the body temperature (about 37°C) and 1 atm pressure. Biochemical reactions move on with dramatic selectivity at a striking speed. Majority of the biomolecules are very large and highly complex and their reactions proceed with complex mechanisms. These are related to the living organisms in the sequence given below:

Living organisms → Organs → Tissues → Cells → Organelles → Biomolecules (proteins, carbohydrates, nucleic acids, lipids, etc).

9.2 THE CELL AND ENERGY CYCLE

The cell is a fundamental functional and structural unit of organisms. We need energy to run, work, jump, and think. Similarly, the cell requires a ready supply of cellular energy for the functions that run and support such activities. The cells require energy for active transport of the molecules between them and environment, across cells, or within cells. So, we require a supply of energy-rich food molecules which are oxidised to supply the needed cellular energy. Cells get energy through oxidation taking place in a sophisticated and controlled manner by the means of enzymes that are biocatalysts. A part of the energy in cells is conjugated with the formation of ATP (adenosine triphosphate, driving many chemical reactions in the cell).

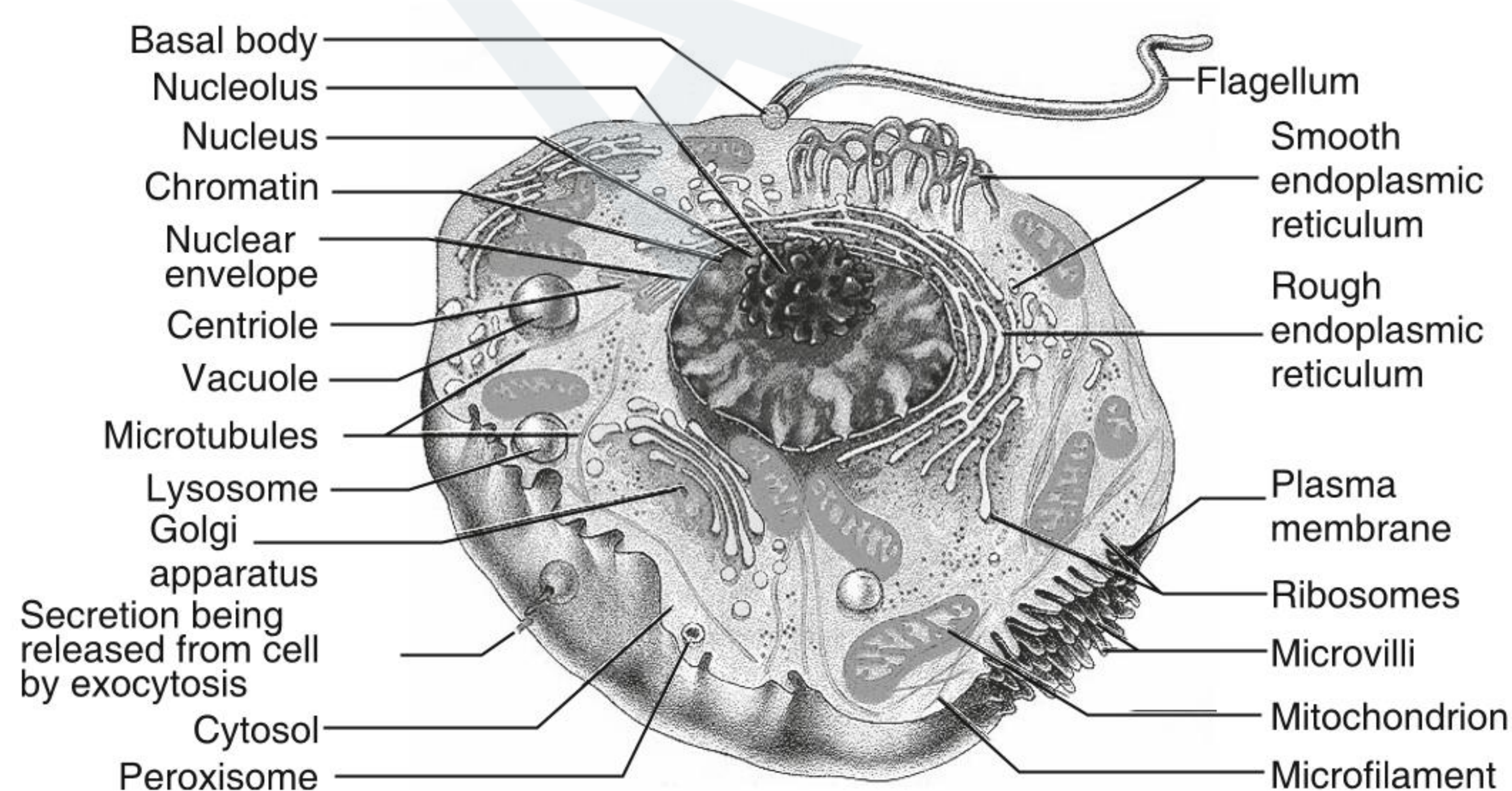
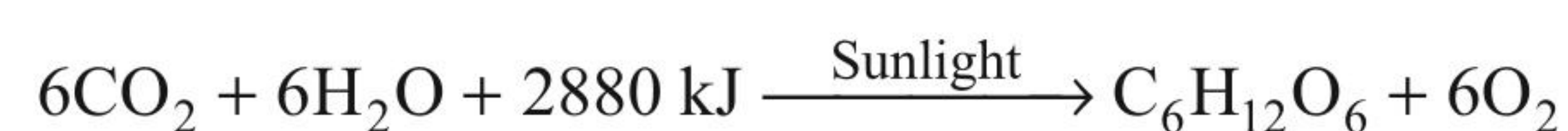


Fig. 9.1 Structure of a cell

There are specific reactions that are endergonic, i.e., in their case the Gibbs energy $\Delta G > 0$ and intrinsically seem to be thermodynamically forbidden. However, such reactions can be made to go ahead in the wanted direction by coupling them with some appropriate exergonic reactions having $\Delta G < 0$. Now, coupling the reaction implies that the two reactions are made to take place at the same time. The conversion of ATP to ADP (adenosine diphosphate) is extremely exergonic ($\Delta G^\ominus = -31.0 \text{ kJ mol}^{-1}$) and can run any thermodynamically forbidden reaction in the wanted direction. This usually happens in many metabolic processes going on in our body.

9.2.1 PHOTOSYNTHESIS AND ENERGY

The sun is the fundamental source of energy for life processes. During the process of photosynthesis, green plants draw energy from the sun to form glucose and oxygen using CO_2 and H_2O . It is a complex mechanism that occurs in a series of steps leading to the net reaction.

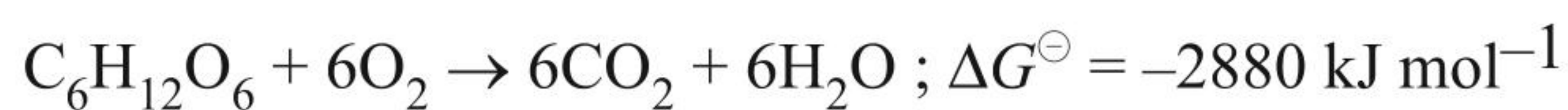


The oxygen formed in photosynthesis is the source of atmospheric oxygen. Photosynthesis usually occurs in a sequence of light reactions that take place in the presence of light energy only and a series of dark reactions that can proceed in dark because they do not rely on light energy. The dark reactions use the high energy formed by the hydrolysis of ATP to proceed. Chloroplasts available in the plant cell absorb the released energy. Through a series of reactions, water is oxidised to oxygen and the energy thus released is pooled in the bonds of energy storage compounds like ATP. In fact, ATP runs these dark reactions that convert CO_2 and H (from water) into glucose and other carbohydrates.

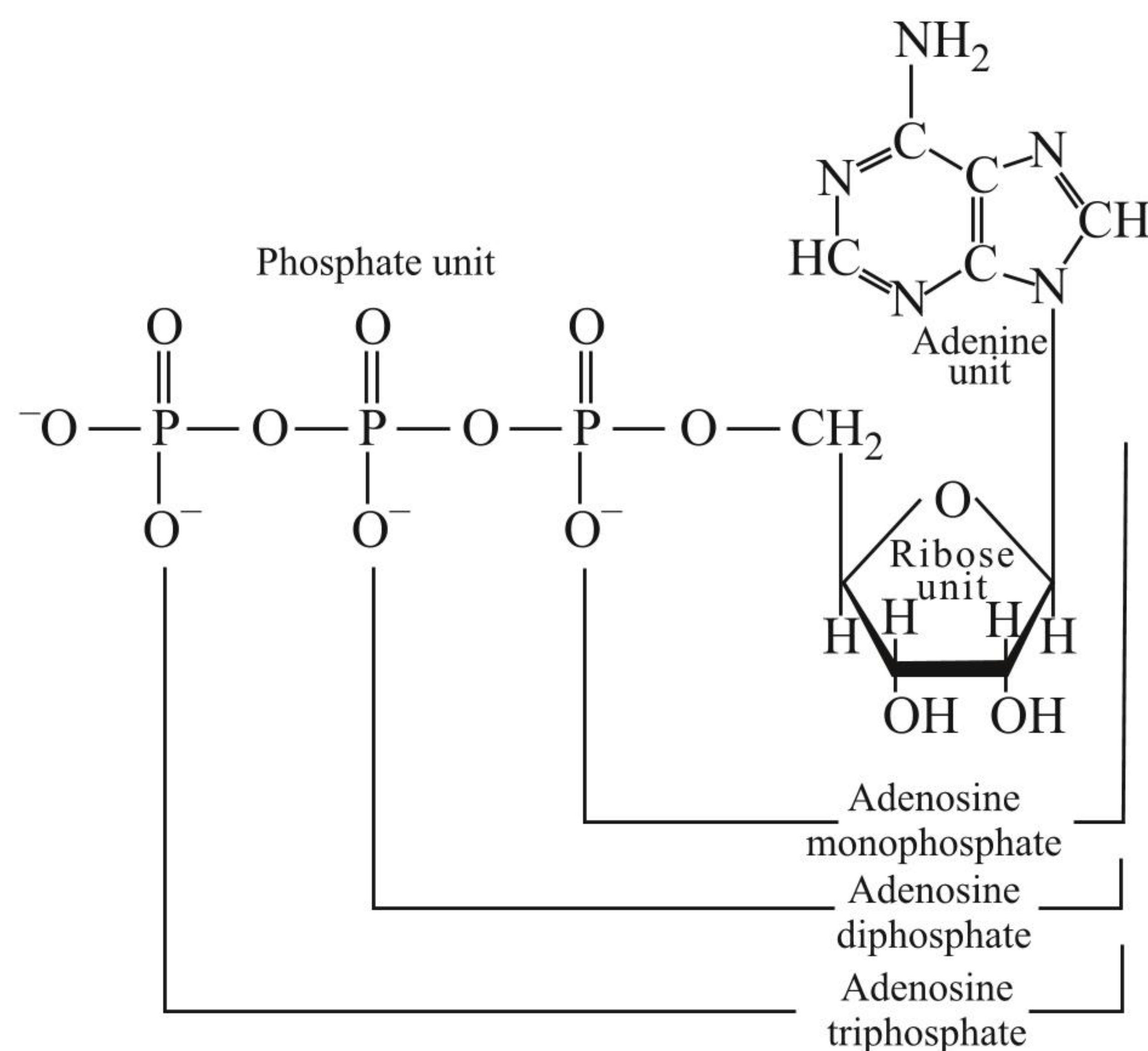
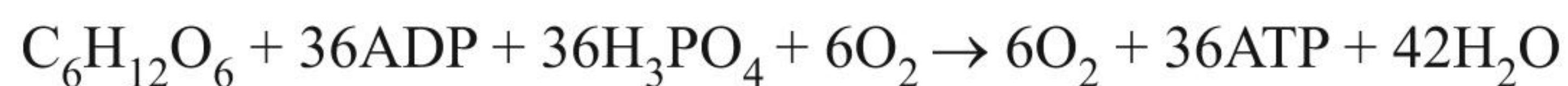
With the availability of an appropriate catalyst, ATP releases energy through a three-step hydrolysis of the (P—O) bond of its triphosphate groups (P—O bond). The first step involves the hydrolysis of ATP to ADP and the release of 31 kJ mol^{-1} Gibbs energy. The second step sees the conversion of ADP into AMP (adenosine monophosphate) accompanied by the production of approximately the same amount of energy. In the final step of the hydrolysis of AMP to adenosine, just 14 kJ mol^{-1} Gibbs energy is released.

The living plants can convert the glucose formed during photosynthesis into disaccharides, polysaccharides, cellulose, starches, proteins, or oils. The final product relies upon the kind of plants involved and complexity of its biochemistry. Hence the

plants are the primary source of energy for humans and animals. The phenomena can be explained by the oxidation of glucose which is the opposite of photosynthesis.



A part of energy is utilised and a part of it is pooled leading to the next reaction:



The high energy phosphate bonds of ATP are shown in the above figure. A large amount of energy is produced following the hydrolysis. In the figure, all the constituent units (e.g., phosphate, ribose, and adenine) are also depicted.

9.3 CARBOHYDRATES

These are polyhydroxy aldehydes or ketones or substances that form these on hydrolysis and possess at least one chiral atom. The (—OH) group is available in the form of hemiacetals or hemiketals.

The carbohydrates are stored in animal body as glycogen which

is also known as animal starch because its structure is highly branched like amylopectin. It is found in liver, muscles, and brain as well as in fungi and yeast. When the body requires glucose, the enzymes break glycogen to glucose.

Importance of carbohydrates: They are indispensable for both plant and animal lives. These are utilised as the storage molecules in the form of starch in plants and glycogen in animals. The cell wall of bacteria and plants consists of cellulose. Carbohydrates are present in biosystem in combination with several proteins and lipids.

9.3.1 CLASSIFICATION

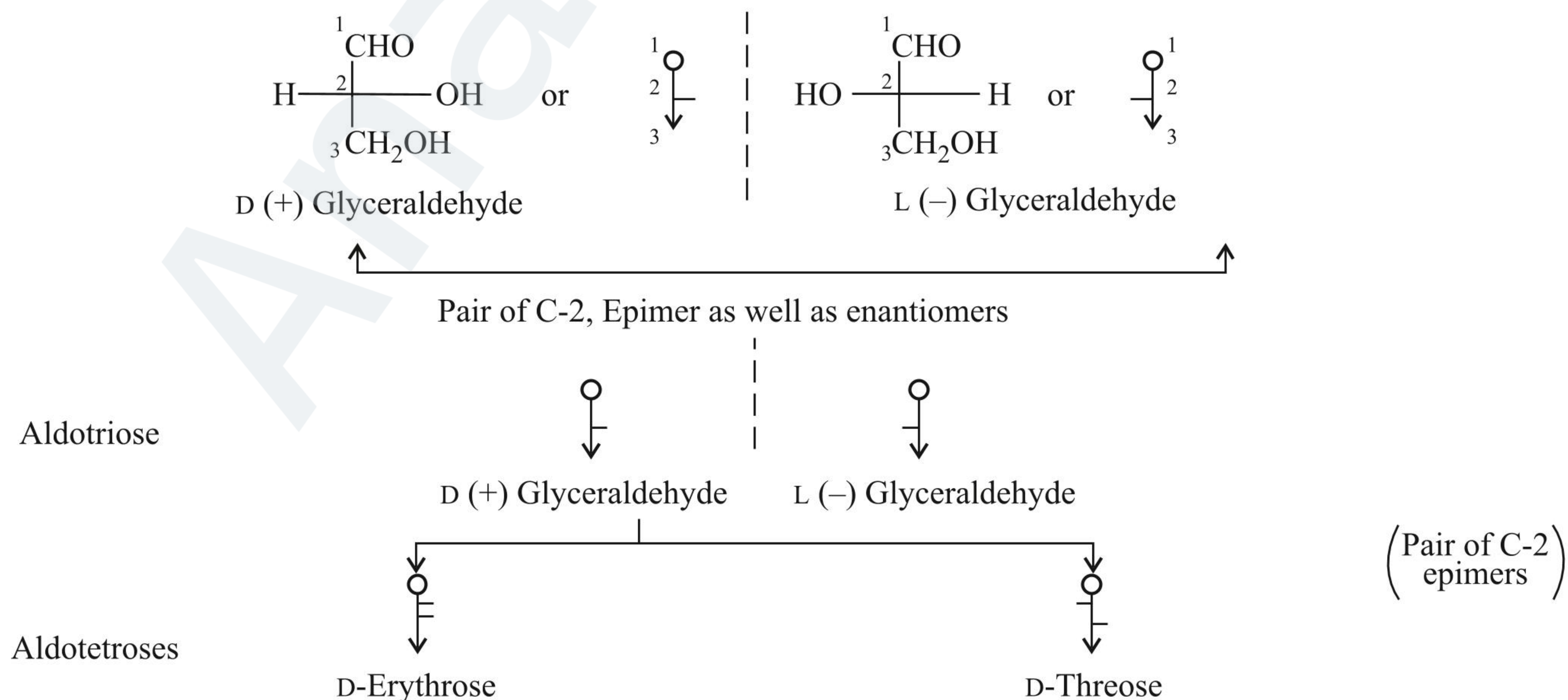
- Monosaccharides:** They are the simplest carbohydrates which cannot be hydrolysed to smaller molecules (Formula: $(\text{CH}_2\text{O})_n$, where $n = 3 - 7$). They are sweet and crystalline, and are called sugars.
- Oligosaccharides:** These carbohydrates on hydrolysis give two to nine molecules of monosaccharides classified as di-, tri-, tetra-saccharides, etc. For example, sucrose, maltose, lactose, and raffinose, etc. They are also called sugars.
- Polysaccharides:** These carbohydrates, on hydrolysis, give a large number of monosaccharide, e.g., starch, cellulose, etc. They are also called non-sugars.

9.3.2 REDUCING AND NON-REDUCING SUGARS

Those sugars which reduce Fehling's and Tollens solutions are called reducing sugars and those which do not reduce these reagents are called non-reducing sugars. All the monosaccharides and disaccharides, except sucrose, are reducing sugars, whereas all the polysaccharides are called non-reducing carbohydrates.

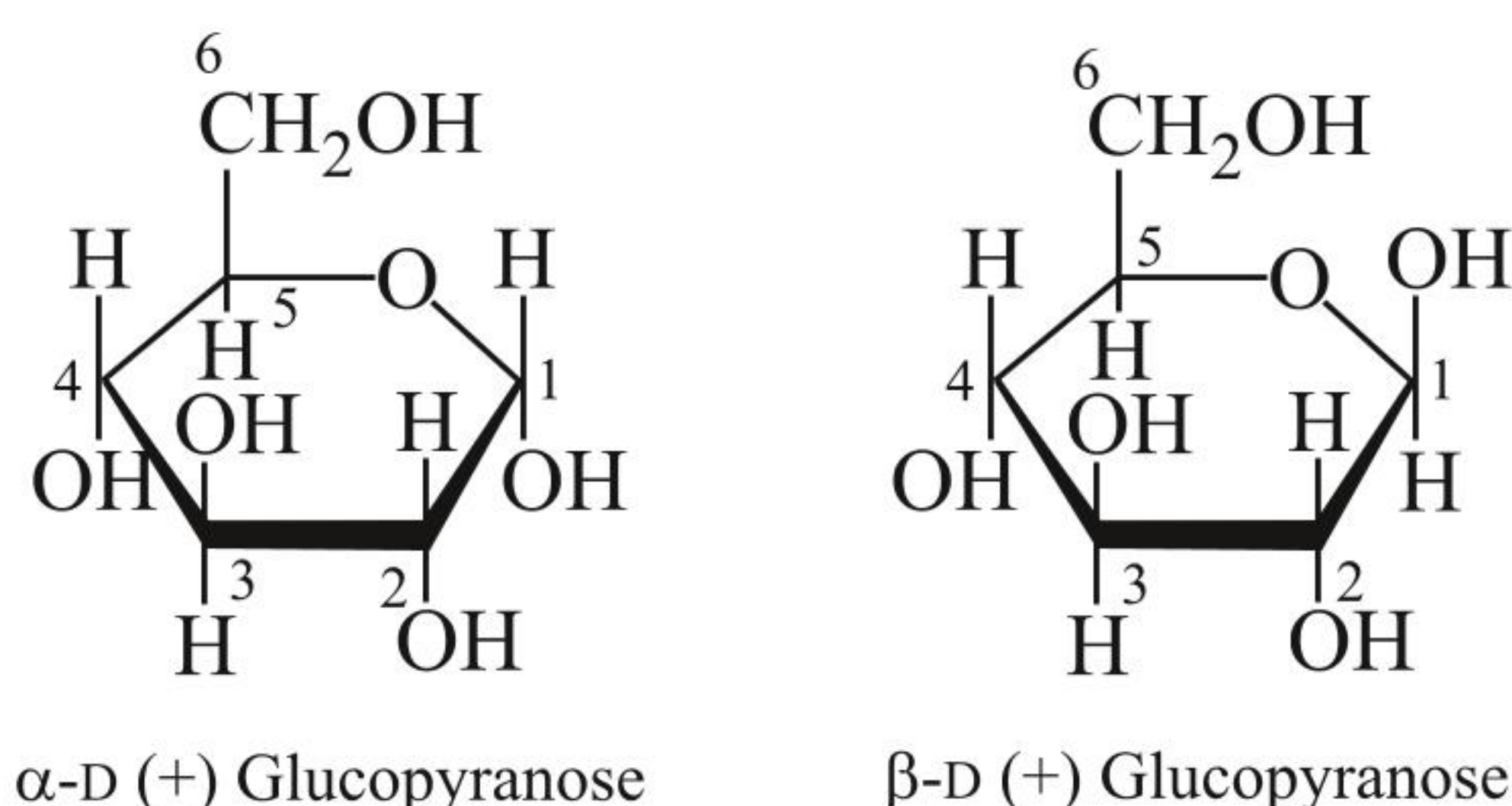
9.3.3 CLASSIFICATION OF ALDOLS: D AND L

Symbols D and L refer to the relative configuration of the (—OH) group at the penultimate carbon w.r.t. glyceraldehydes taken as standard. D refers to the (—OH) group that lies on the right hand side and L refers to the (—OH) group that lies on the left hand side.

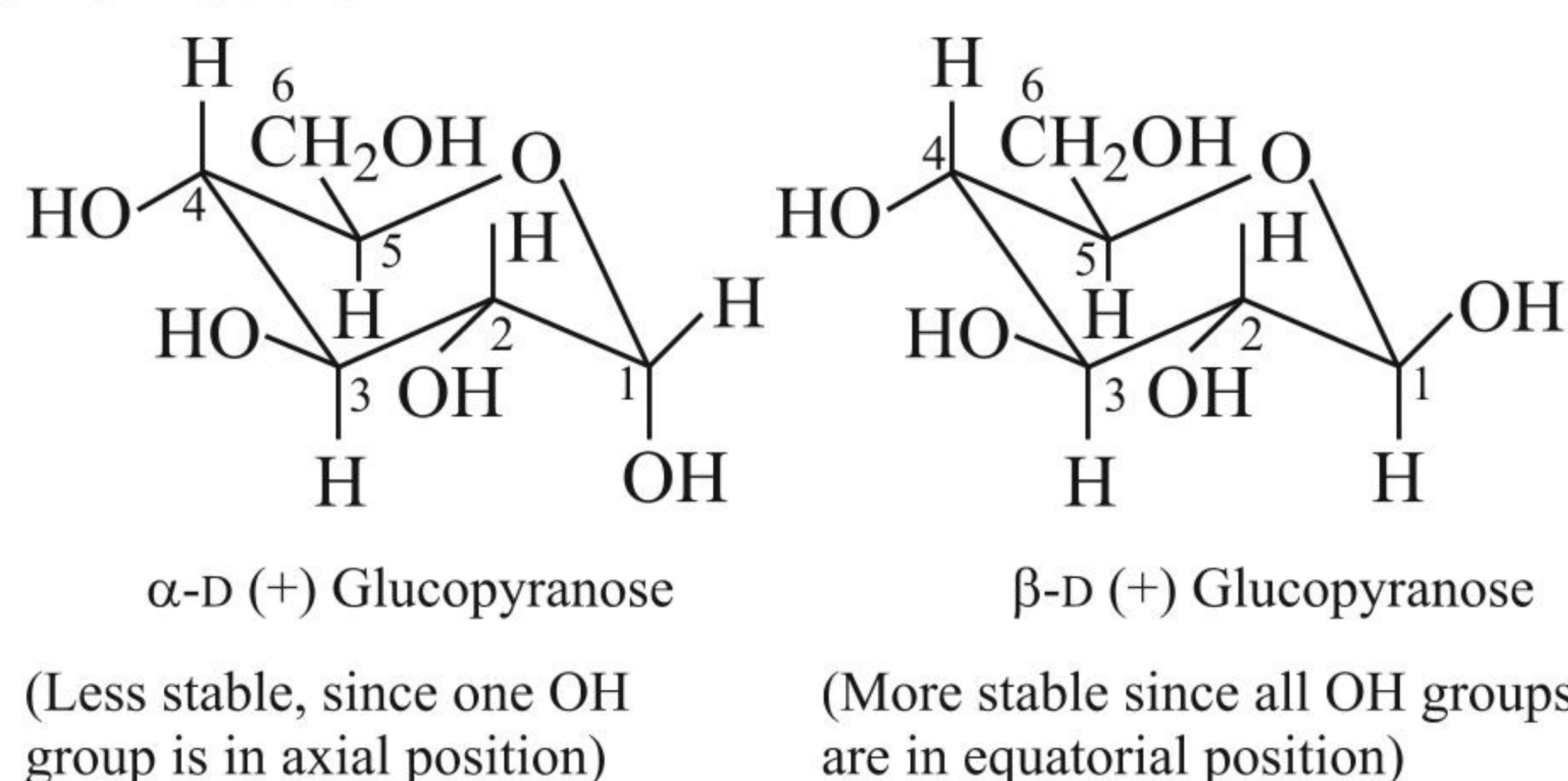


ii. Haworth representation: Cyclic structure of glucose was established by English chemist W.N. Haworth (who received Nobel prize for carbohydrate chemistry in 1937). The OH

groups in Fischer projection on the R.H.S. are shown below the plane of the ring and those on the L.H.S. above the plane of the ring in Haworth structures. For example,



iii. **Chair-form conformation structures:** Haworth projection structures are transformed to the chair conformation. The OH groups which are below the plane of the ring in Haworth structures are also placed below the plane in the chair conformation.



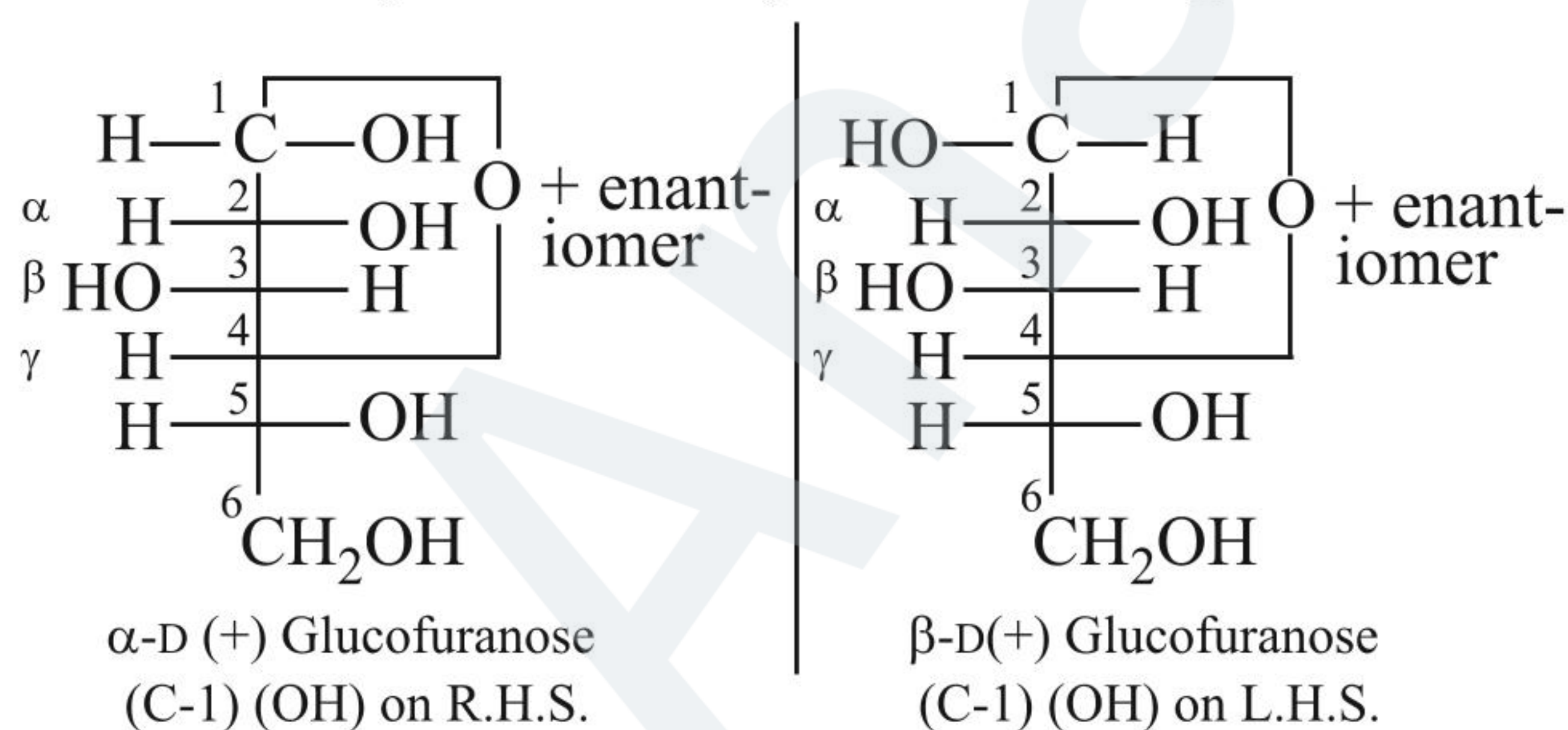
iv. **CHO reacts with C-4 OH group to give two anomeric glucose:** In this case, five-membered ring (furanose) is

formed. The word furanose refers to five-membered ring like

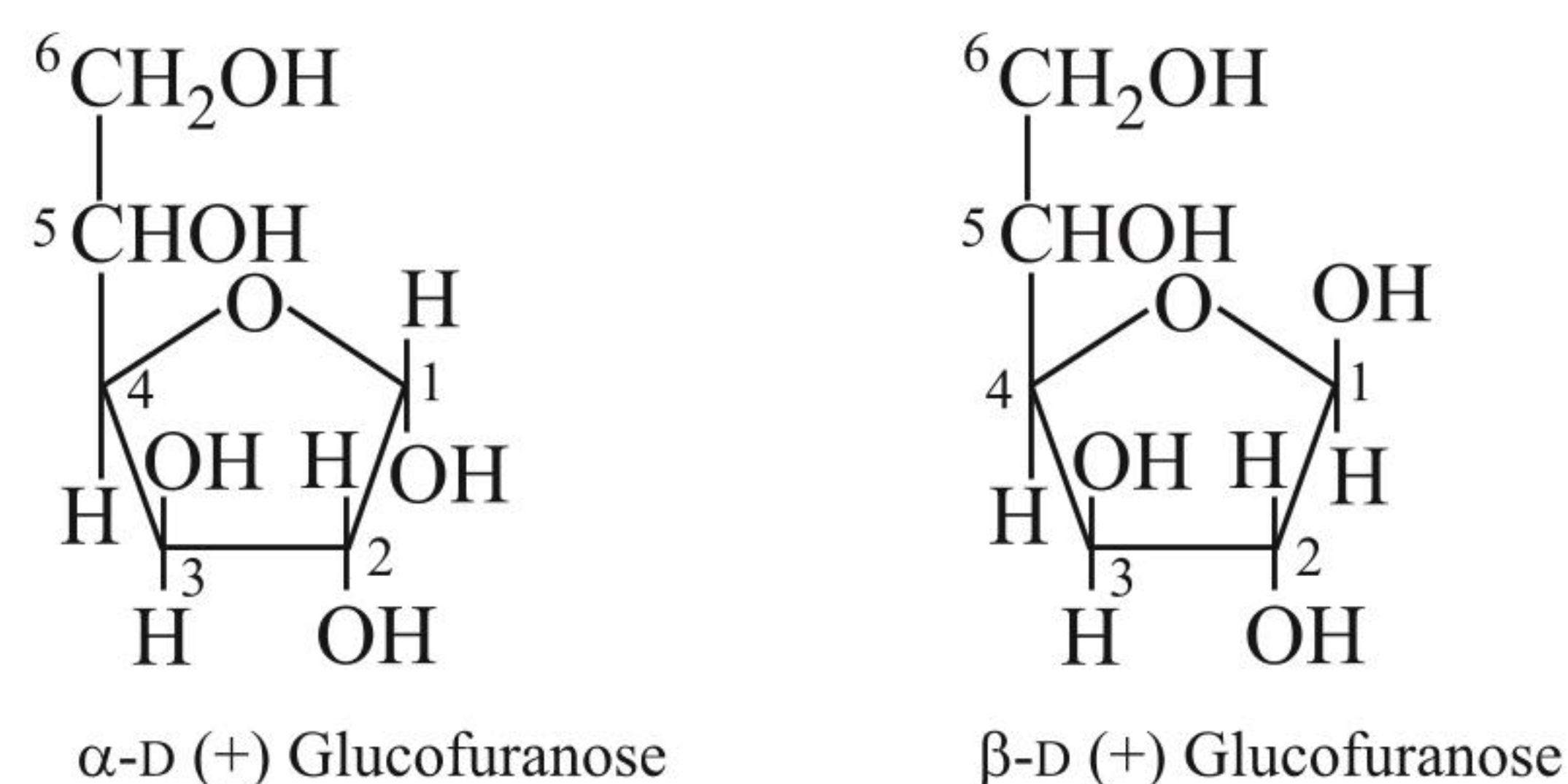
in furan () or this refers to γ -linkage, since hemiacetal

linkage is between C-1 and C-4 γ -C atom.

Not all carbohydrates exist in equilibrium with six-membered hemiacetal rings; in several instances the ring is five-membered, e.g., in fructose. However, glucose occurs in nature only in pyranose form (six-membered), but to a small extent glucose exists in equilibrium with five-membered (furanose form) hemiacetal ring.

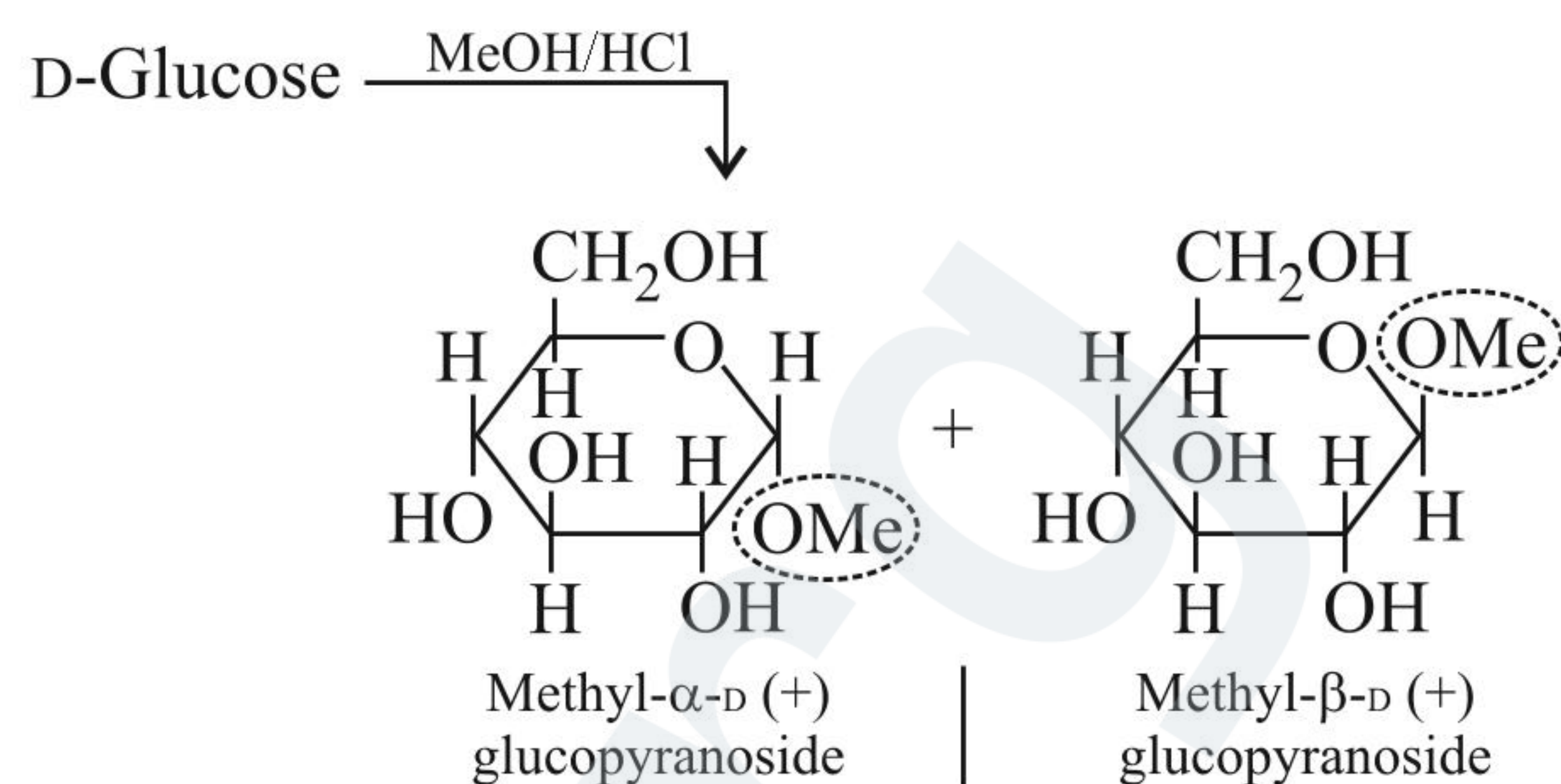


Haworth representation:



9.3.8 STRUCTURES OF GLUCOSIDES

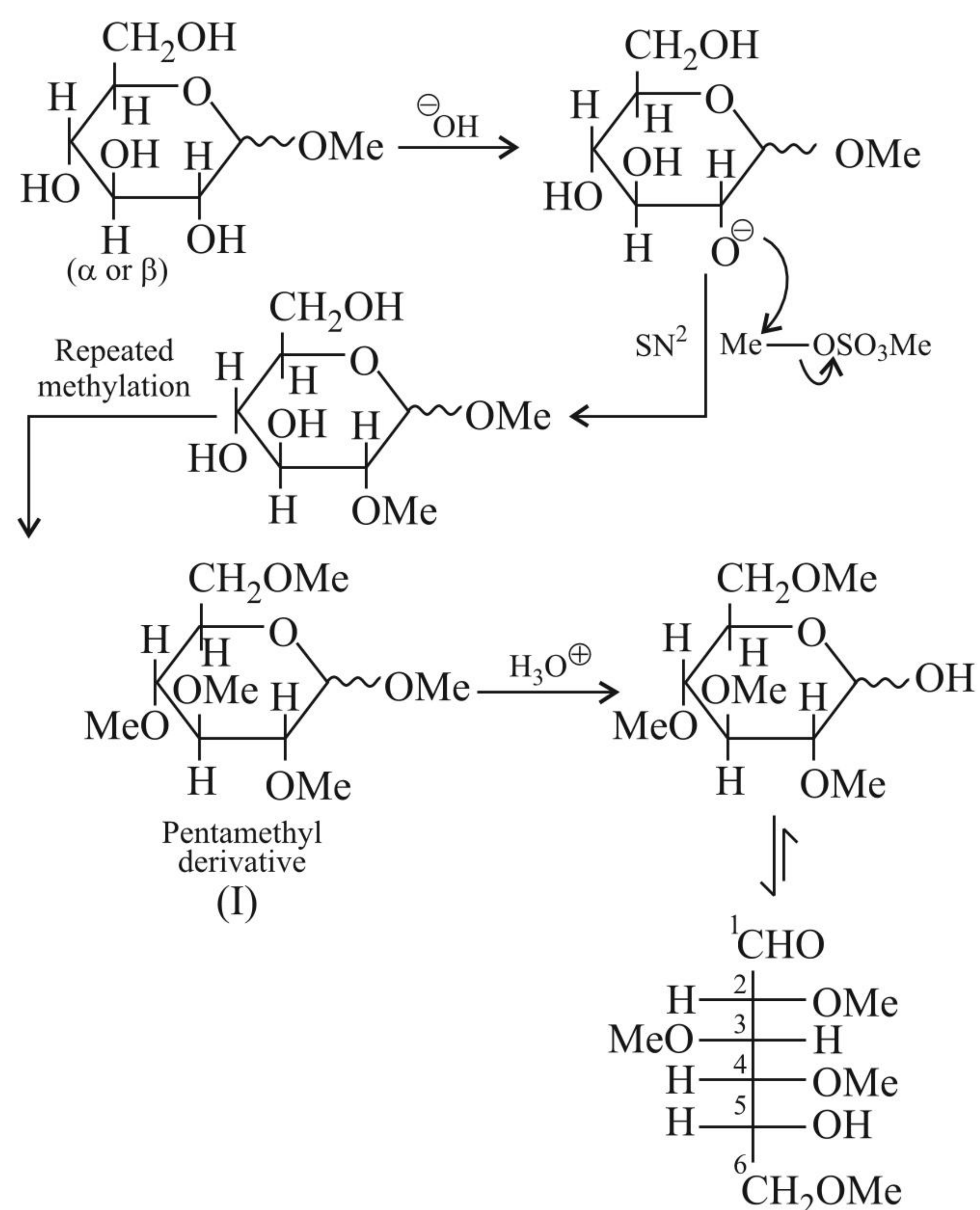
D-Glucose on reaction with MeOH + HCl gives α - and β -D-glucopyranoside.



Methyl glucoside on reaction with excess of $\text{Me}_2\text{SO}_4/\text{NaOH}$ gives pentamethyl derivatives. The OH groups of monosaccharides are more acidic than alcohols because monosaccharides contain many electronegative O atoms, and all of them exert $-I$ effect on the nearby OH groups. In aqueous NaOH, the OH groups are converted to alkoxide ion (RO^-) which reacts with Me_2SO_4 by S_N^2 mechanism and forms methyl ether. This process is called **exhaustive methylation**.

The OMe groups at C-2, C-3, C-4, and C-6 of the penta methyl derivative are ordinary ether groups. These groups are stable in dilute aqueous acid, since ether groups are cleaved by heating with concentrated HBr or HI.

The OMe group at C-1 is different from others because it is part of acetal linkage (it is glucosidic).



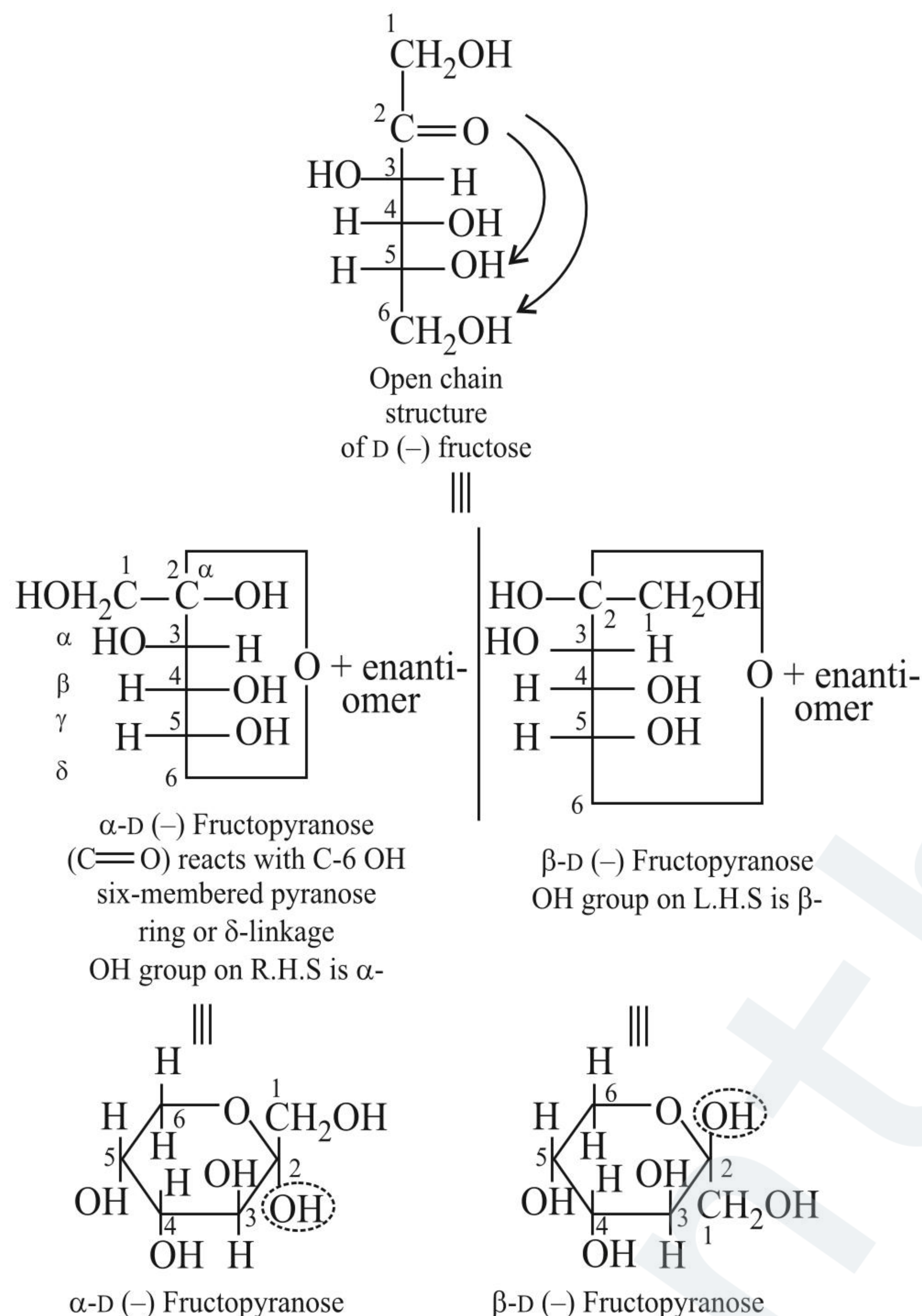
When pentamethyl derivatives are treated with dilute aqueous acid, hydrolysis of the glycosidic OMe group occurs to give

2,3,4,6-tetra-O-methyl-D-glucose. (O in the name refers that the Me groups are attached to O atoms.)

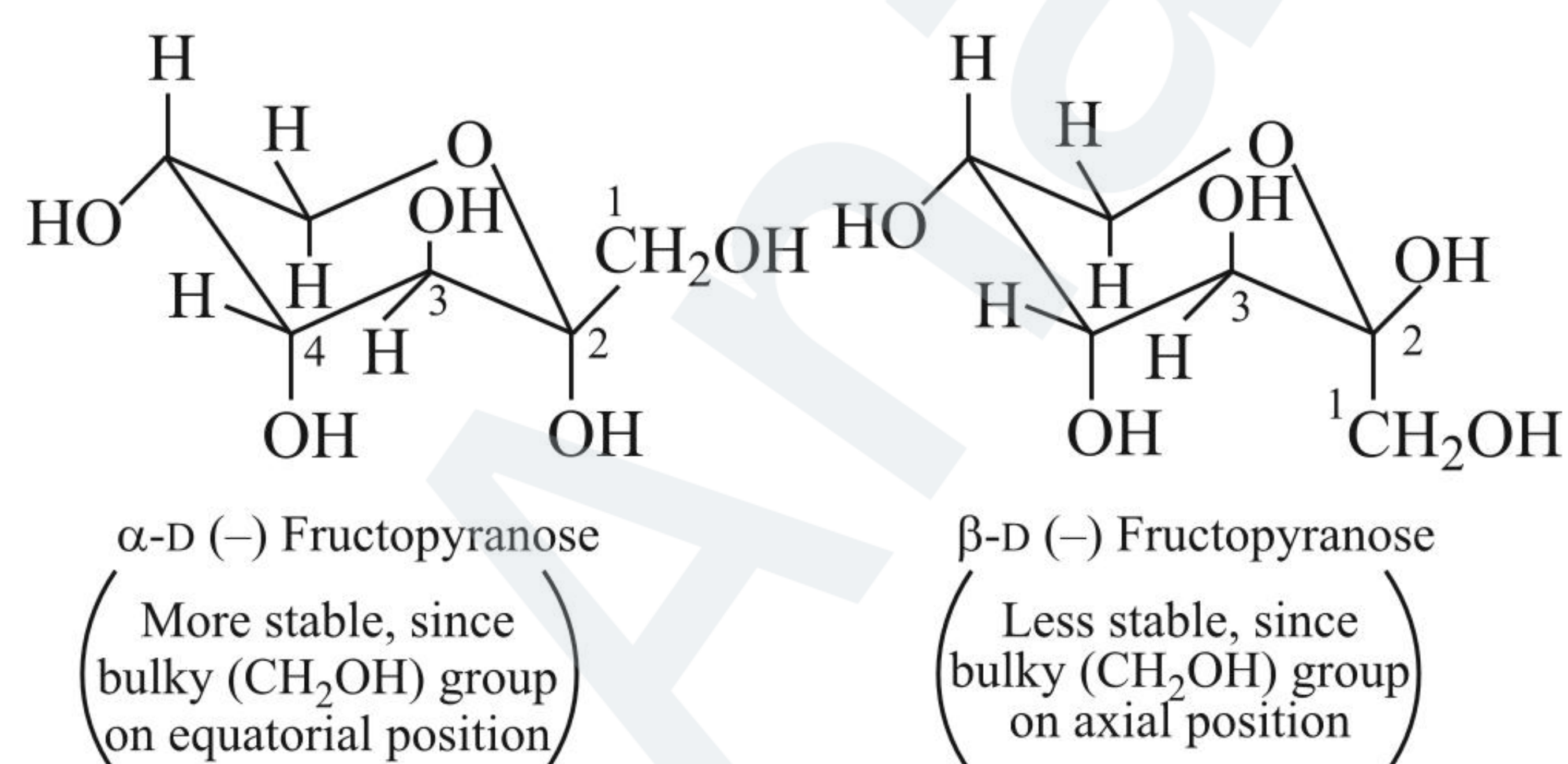
In the open chain structure, there is no Me group at C-5 because it was originally a part of the cyclic hemiacetal linkage of D-glucose.

9.3.9 REPRESENTATION OF STRUCTURES OF FRUCTOSE

i.

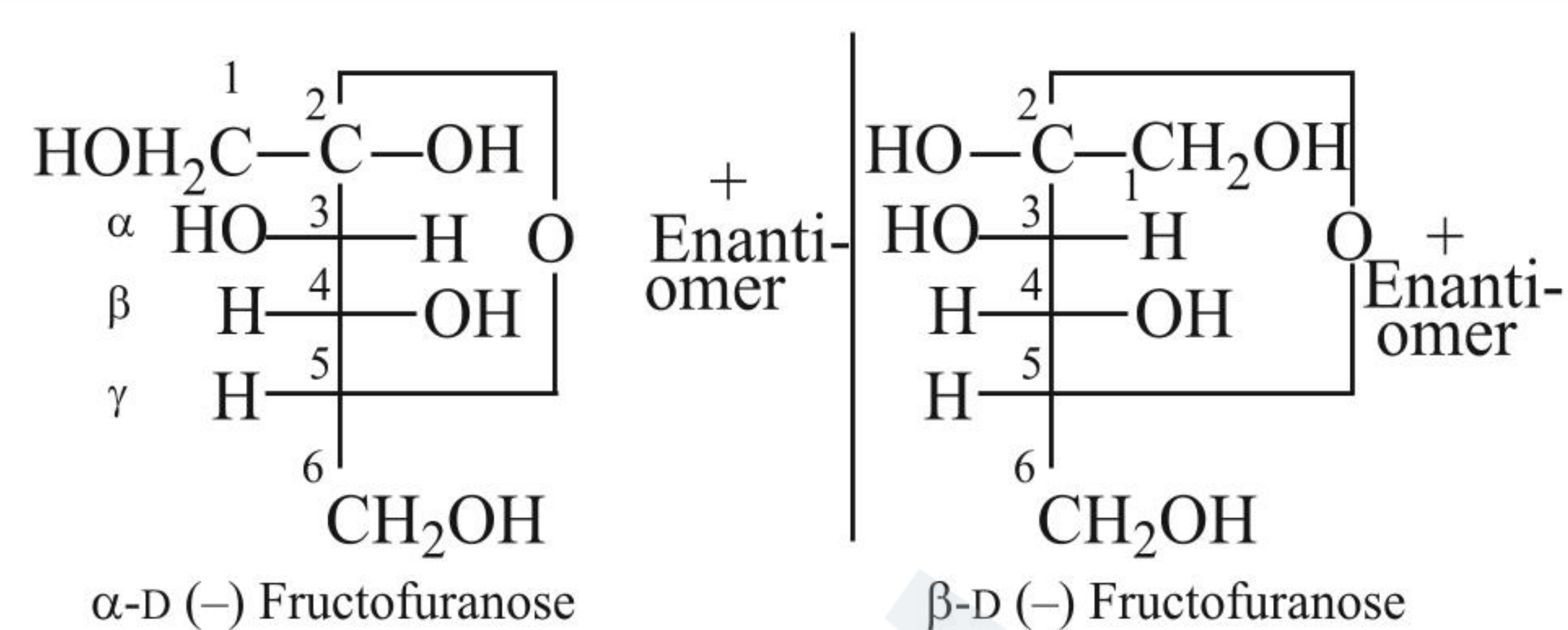


ii. Chair-form conformational structures:

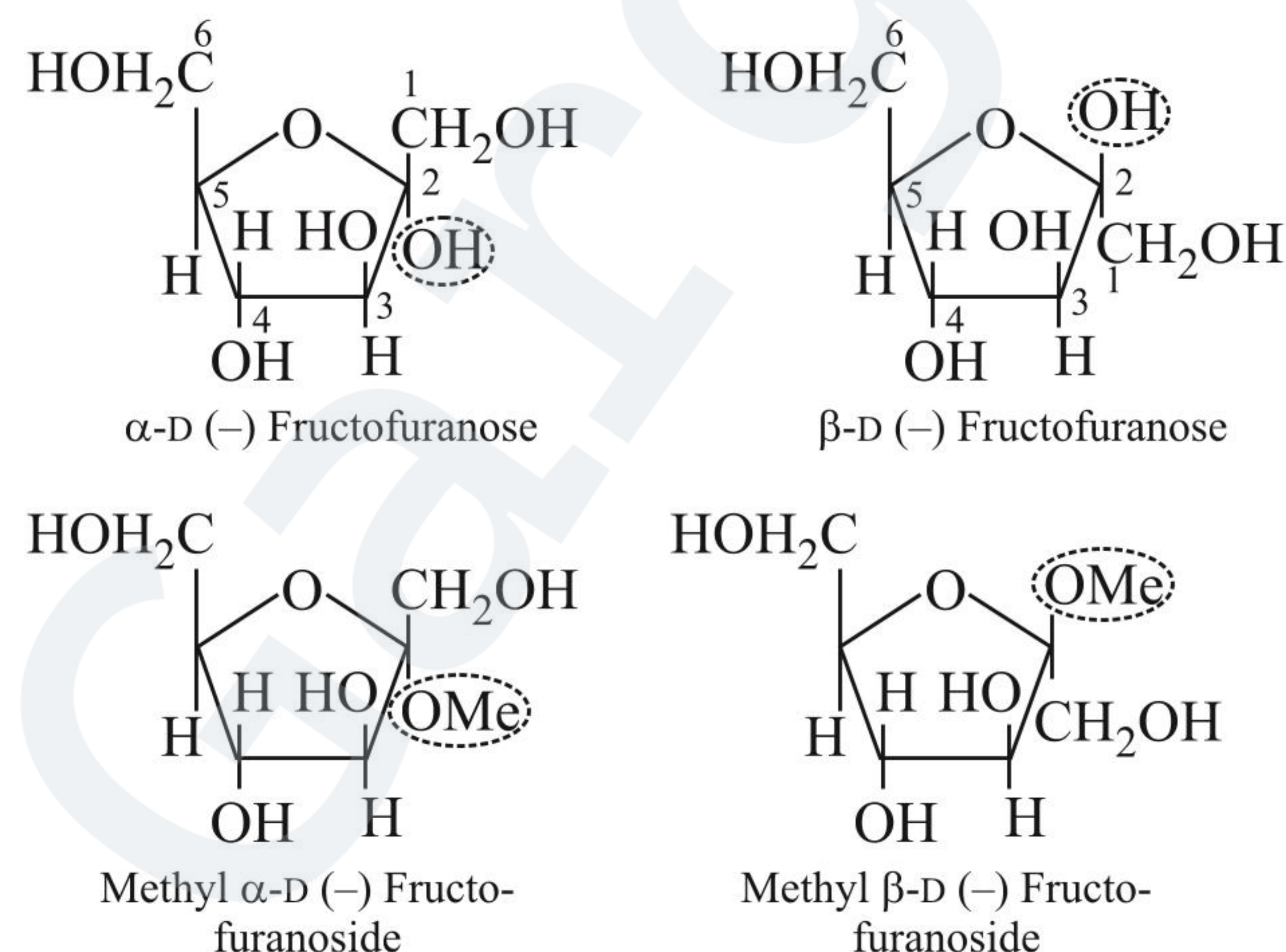


iii. Fructose occurs in nature in furanose form (five-membered cyclic ring) but to a small extent fructose exists in equilibrium with six-membered (pyranose form) hemiacetal ring.

It also exists in two cyclic forms which are obtained by the reaction of (C=O) group with C-5 OH group.



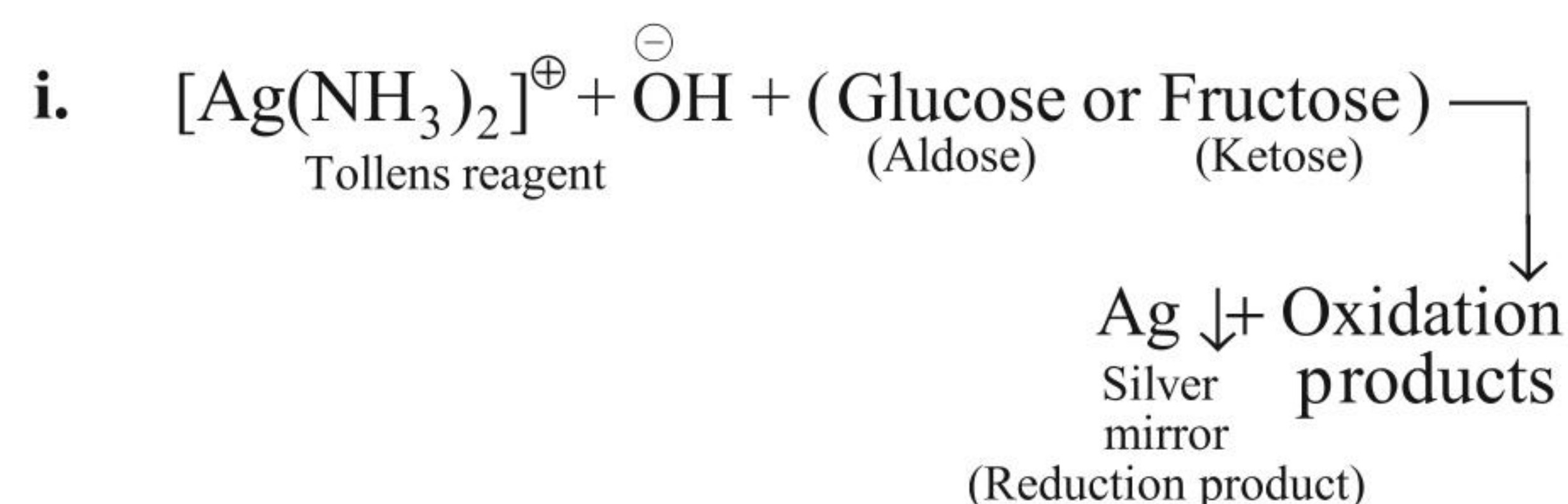
Haworth representation:



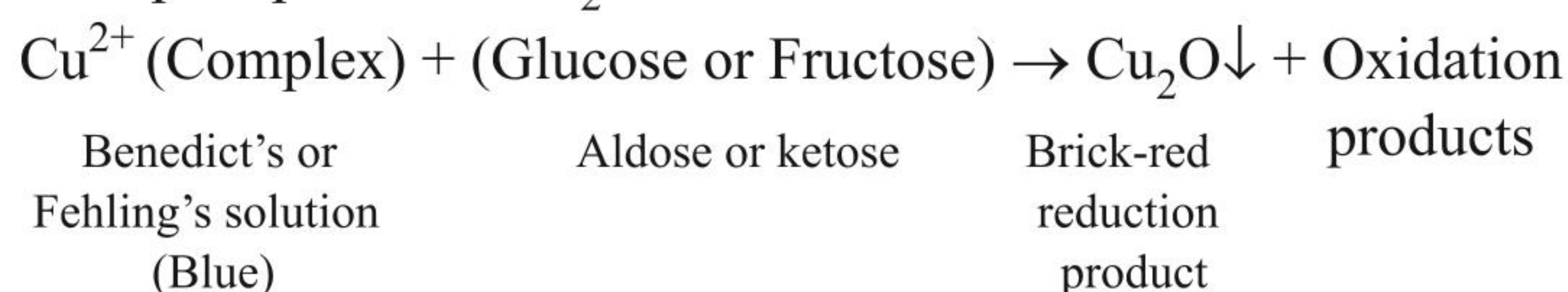
9.3.10 TESTS OF CARBOHYDRATES

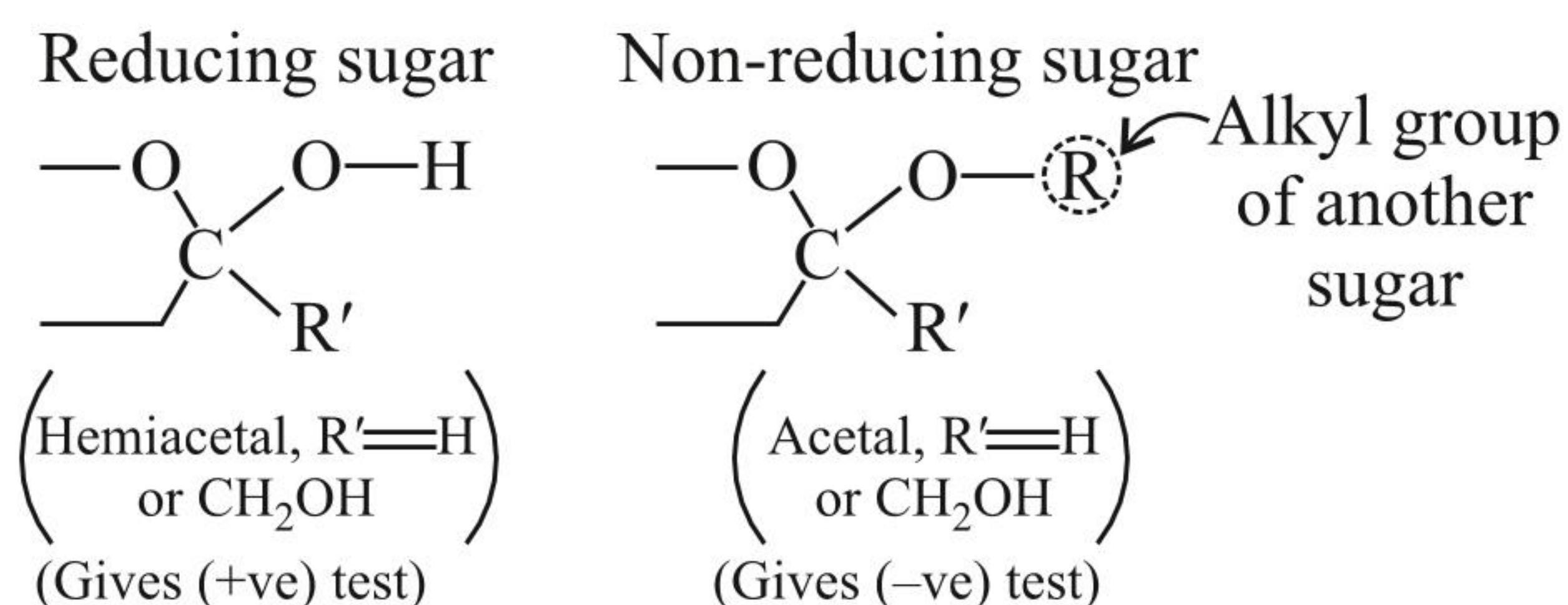
These reagents oxidise CHO to COOH or its salt in basic solution. Both aldoses and ketoses (glucose and fructose) give positive tests with all the reagents mentioned above. The ketosugar (fructose) reacts because it rearranges to an aldose under the basic conditions. All these reagents are in basic medium.

Sugars which give positive tests with these reagents are known as **reducing sugars** and all the carbohydrates which contain a hemiacetal group give positive tests. Carbohydrates which contain only acetal groups and do not give positive tests with these reagents are called **non-reducing sugars**. Acetals do not exist in equilibrium with aldehydes or α -hydroxy ketones in basic media of the test reagents.



ii. Benedict's reagent (an alkaline solution containing a cupric citrate complex) and Fehling's reagent (an alkaline solution containing cupric tartarate complex ion) and their solutions are blue. They oxidise an aldose or ketose and give brick red precipitates of Cu₂O.





1. Barfoed's test: (For monosaccharides, reducing sugars) It is a biochemical test to detect monosaccharides (reducing) sugars in solution devised by the Swedish physician C.T. Barfoed (1815-99). A mixture of ethanoic (acetic) acid and copper (II) acetate $[(\text{CH}_3\text{COO})_2\text{Cu}]$ is added to the test solution and boiled. If any reducing sugars are present a red precipitate of copper (II) oxide (CuO) is formed.

The reaction will be negative in the presence of disaccharide sugars as they are weaker reducing agents.

2. Seliwanoff's test: (For ketonic sugars) It is a biochemical test to identify the presence of ketonic sugars such as fructose in solution. It was devised by the Russian chemist F.F. Seliwanoff. A few drops of the reagent consisting of resorcinol ($\text{HO}-\text{C}_6\text{H}_4-\text{OH}$) crystals dissolved in equal amounts of H_2O and HCl , are heated with the test solution and the formation of a red precipitate indicates the positive test for fructose.

3. Molisch's test: (For carbohydrates) It is a biochemical test to detect the presence of carbohydrates in solution. It was devised by Austrian chemist H. Molisch (1856-1937).

A small amount of alcoholic α -naphthol ($\text{C}_{10}\text{H}_7\text{OH}$) is mixed with test solution and conc. H_2SO_4 is added slowly by the side of test tube. A violet ring is formed at the junction of the two liquids shows the presence of carbohydrates.

ILLUSTRATION 9.1

Distinguish between α -D-glucopyranose (I) and methyl α -D-glucopyranoside (II).

Sol. (I) will give positive and (II) will give negative test with Benedict's or Tollens solution because (I) is cyclic hemiacetal and (II) is a cyclic acetal.

ILLUSTRATION 9.2

Write the structures obtained by the epimerisation of α -D-glucose at C-2, C-3, and C-4 (OH) groups.

Sol.

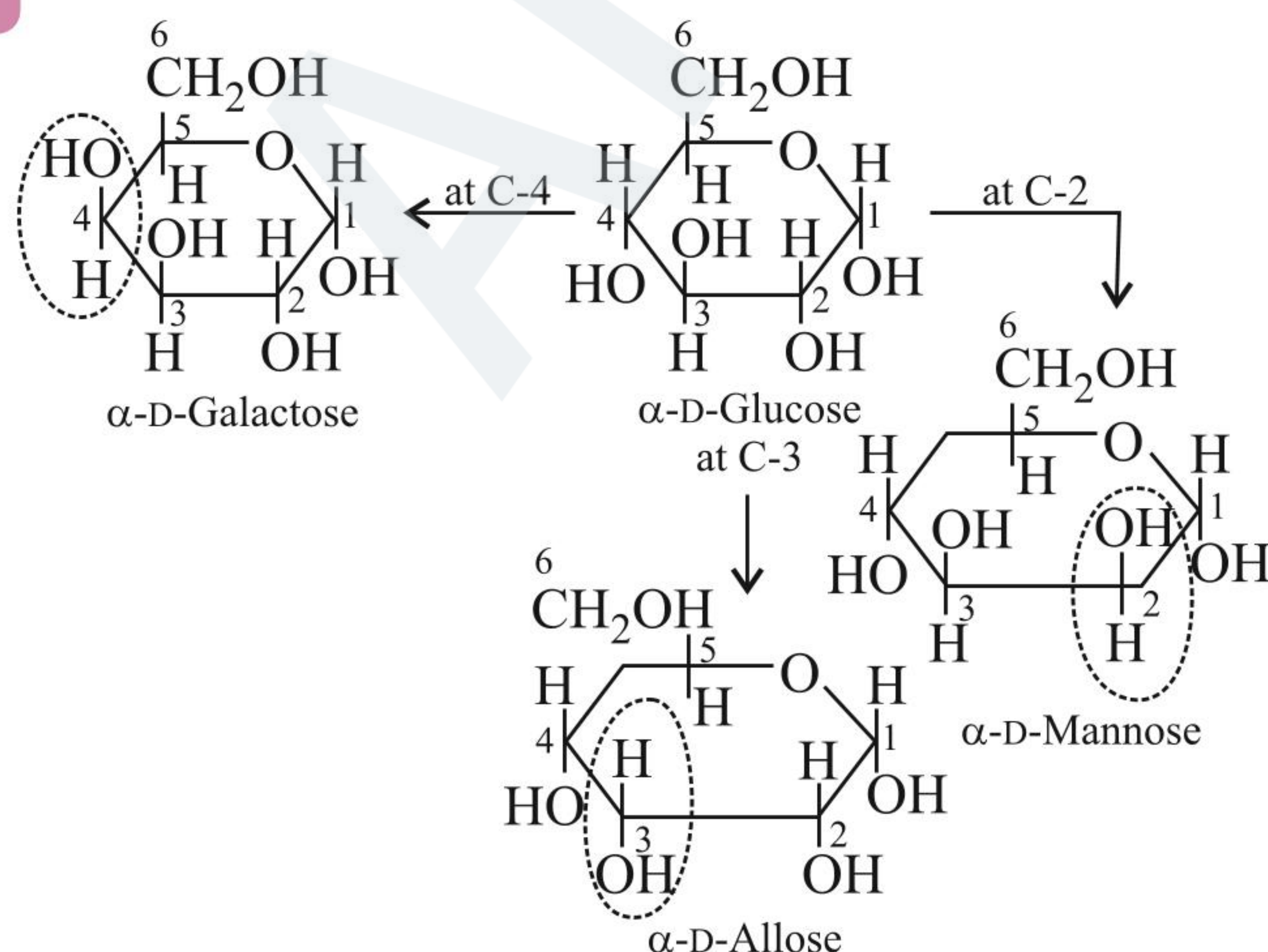


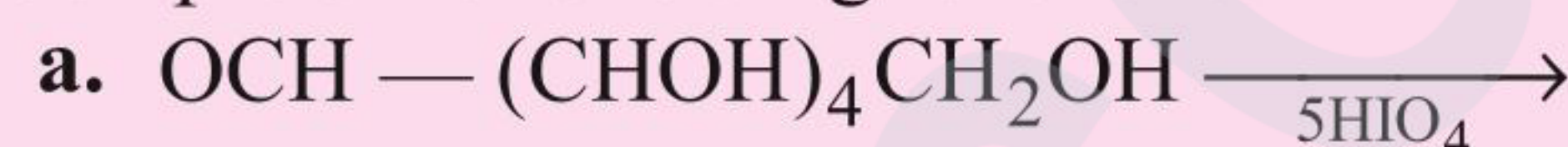
ILLUSTRATION 9.3

Explain, in neutral or basic aqueous solutions, glycosides do not show mutarotation, but in acidic medium they show mutarotation.

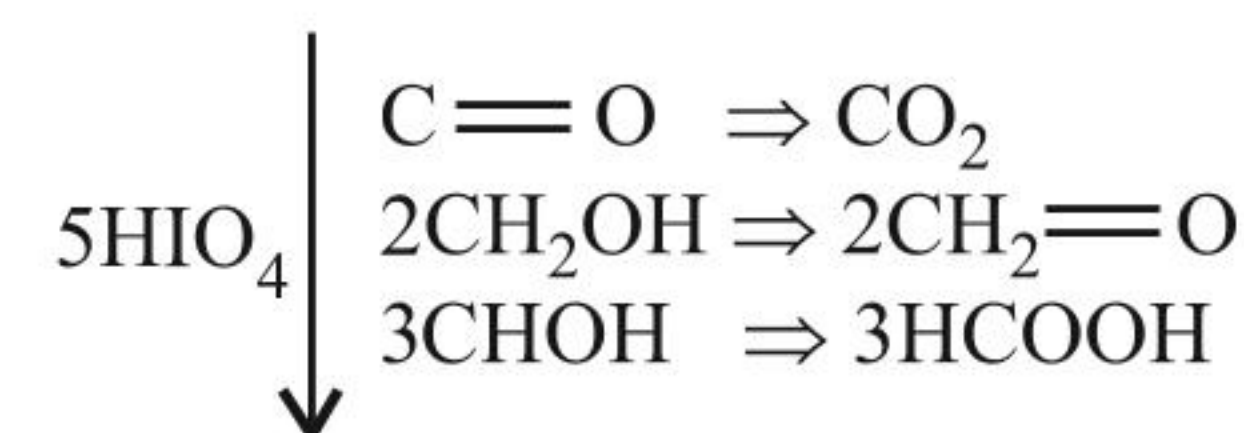
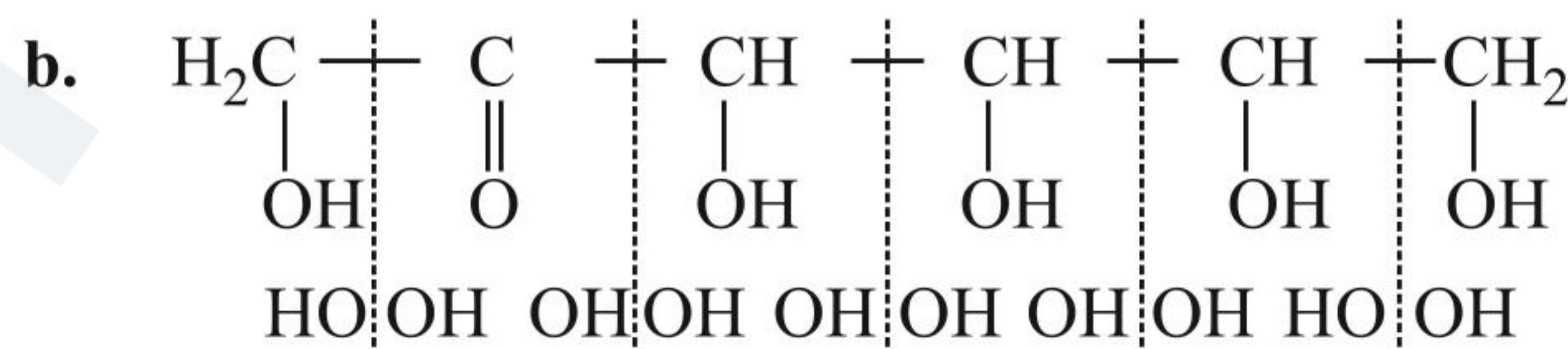
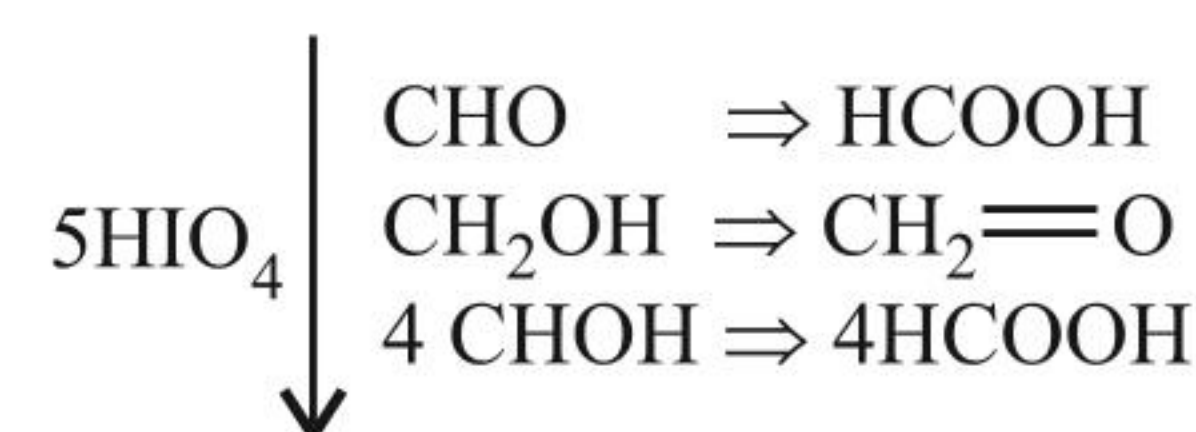
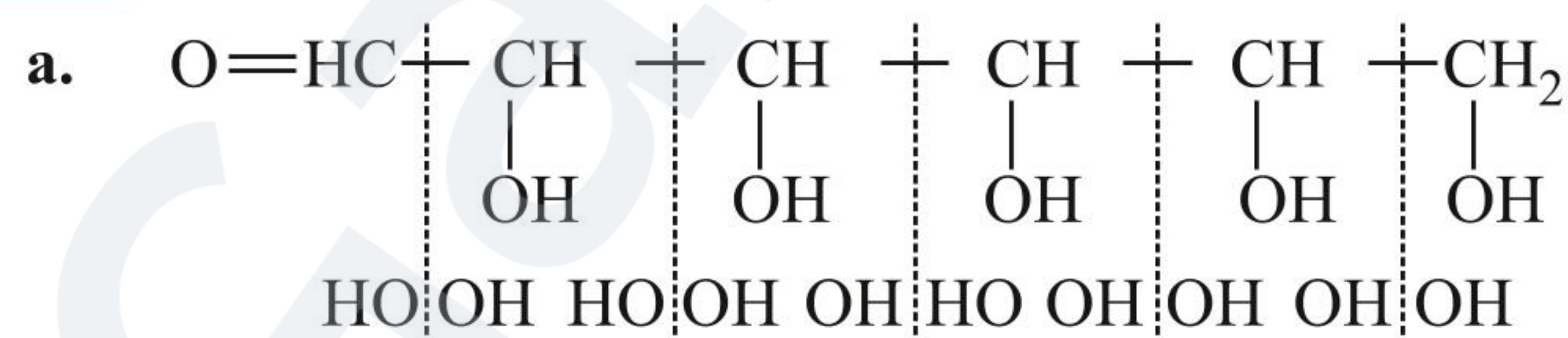
Sol. Since glycosides are acetals, they undergo hydrolysis in aqueous acid to form cyclic hemiacetals which undergo mutarotation.

ILLUSTRATION 9.4

Complete the following reactions:



Sol.

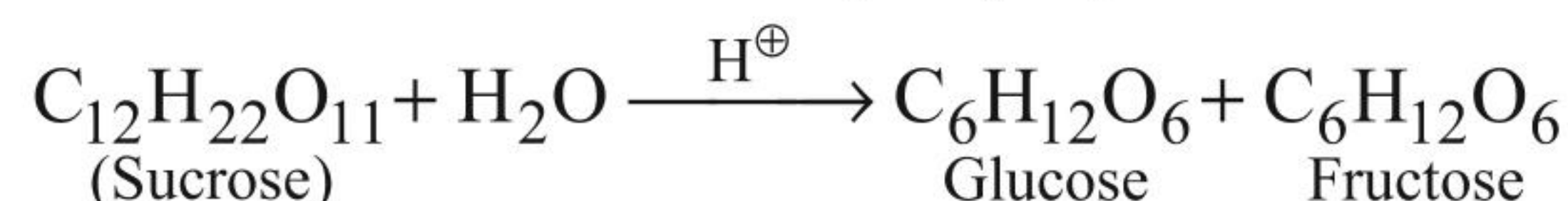


9.3.11 GLUCOSE

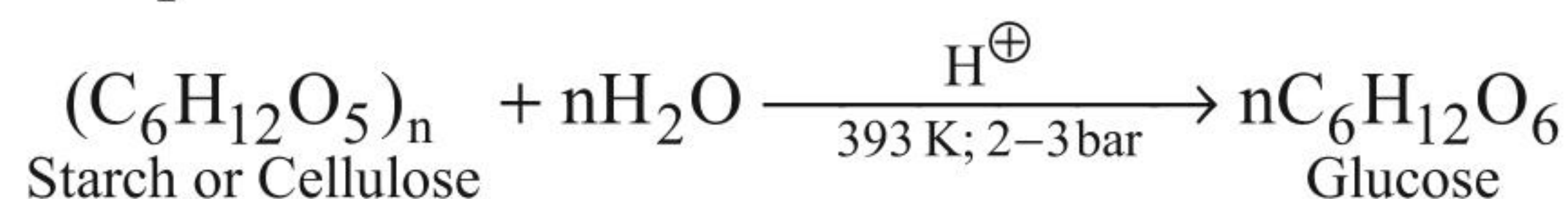
Glucose is found in nature in free as well as in combined form. It is available in sweet fruits and honey, e.g., ripe grapes have ~ 20% of glucose.

Preparation of Glucose

a. From sucrose (cane sugar): When sucrose is boiled with dil. HCl or H_2SO_4 in alcoholic solution, glucose and fructose are formed in equal proportions.



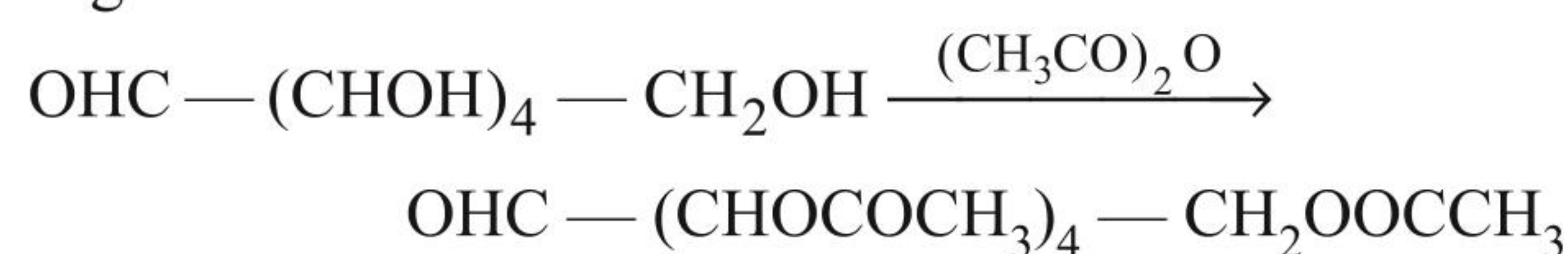
b. From starch: Industrially, glucose is manufactured by the hydrolysis of starch by boiling it with dil. H_2SO_4 at 393 K under pressure.



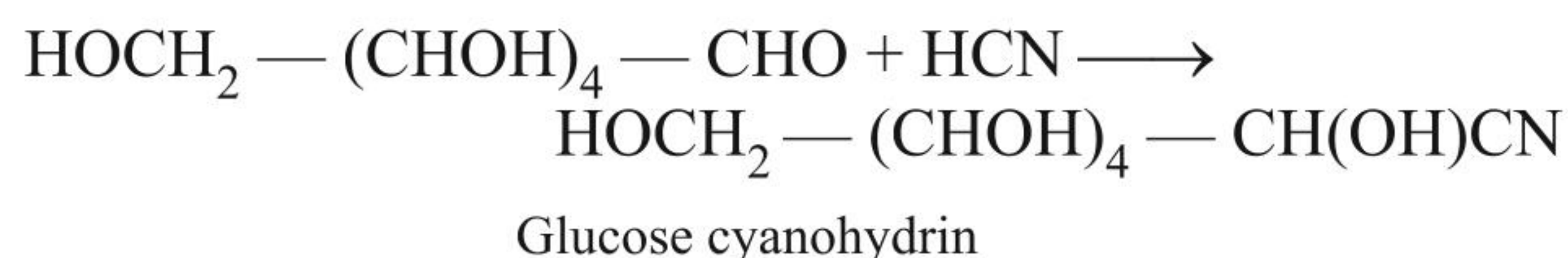
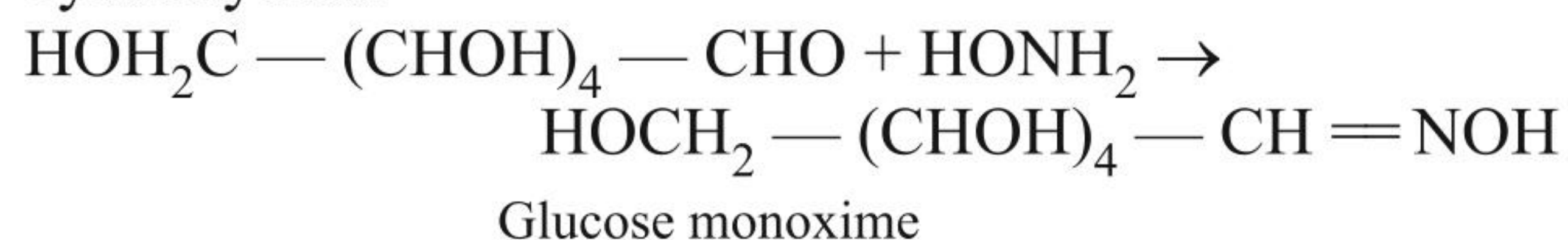
Properties of Glucose

Glucose possesses one aldehyde group, one primary ($-\text{CH}_2\text{OH}$) group, and four secondary ($-\text{CHOH}$) hydroxyl groups. It gives the following reactions:

- a. Acetylation of glucose with acetic anhydride forms a pentaacetate, proving the presence of five hydroxyl groups in glucose.

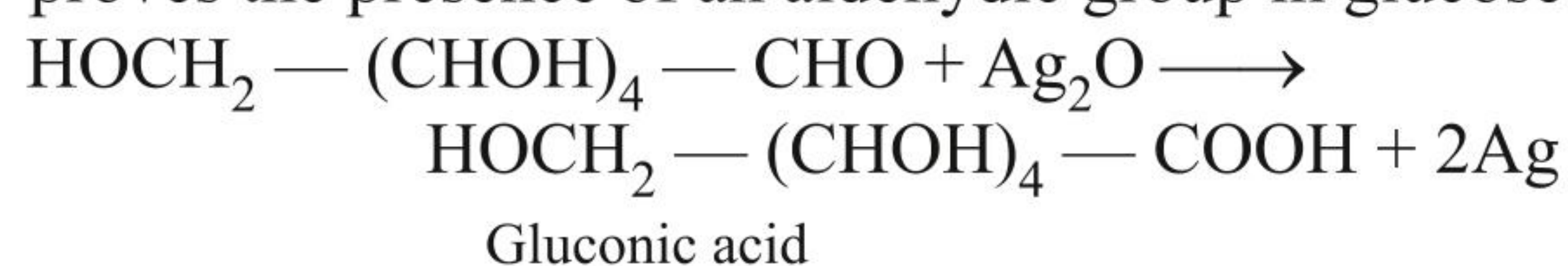


- b. Glucose reacts with hydroxylamine to form monoxime and adds up a molecule of hydrogen cyanide to form a cyanohydrin.

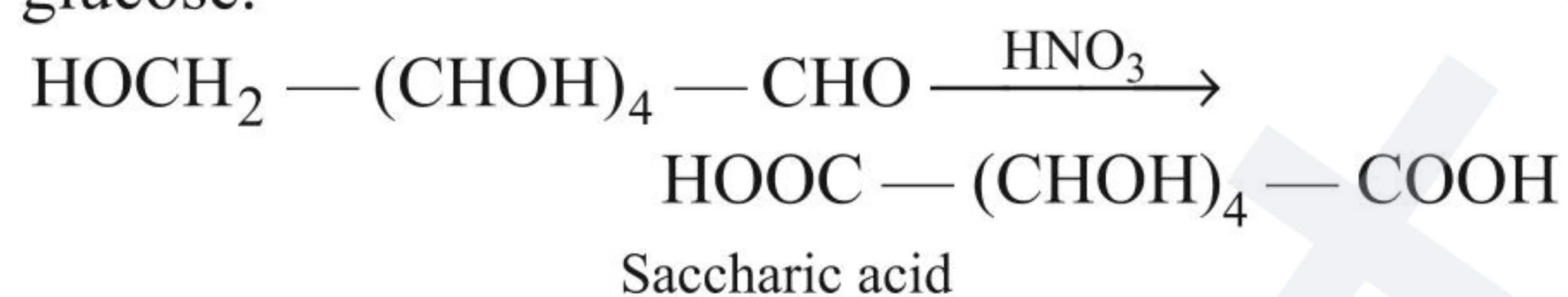


The above reactions validate the occurrence of a carbonyl group in glucose.

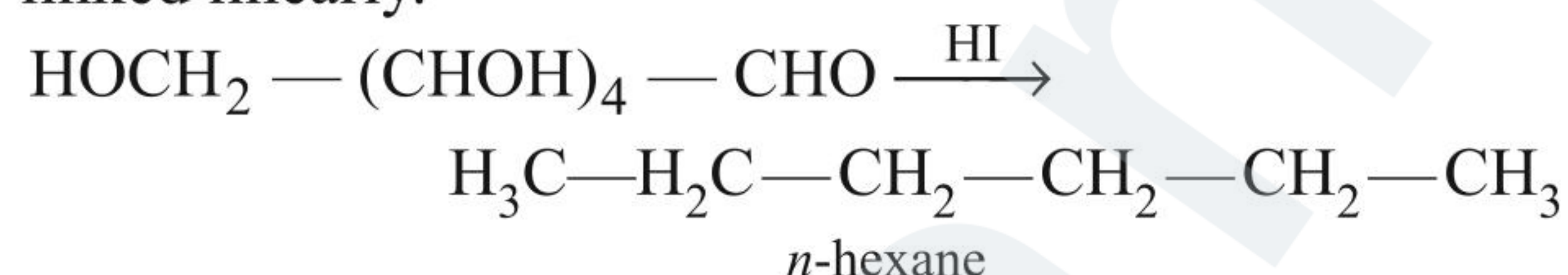
- c. Ammoniacal silver nitrate solution (Tollens reagent) is reduced to metallic silver by glucose. Similarly, Fehling's solution is reduced to reddish brown cuprous oxide. On the other hand, it itself gets oxidised to gluconic acid. This proves the presence of an aldehydic group in glucose.



- d. Both glucose and gluconic acid yield a dicarboxylic acid (saccharic acid) on oxidation with nitric acid. This confirms the availability of a primary alcoholic group in glucose.



- e. On prolonged heating with HI, glucose forms *n*-hexane, indicating that all the six carbon atoms in glucose are linked linearly.



- f. D-Glucose on reaction with 3 moles of phenyl hydrazine gives glucose phenylhydrazone which is soluble. If an excess of phenylhydrazine is utilised, a dihydrazone, called osazone, is formed.

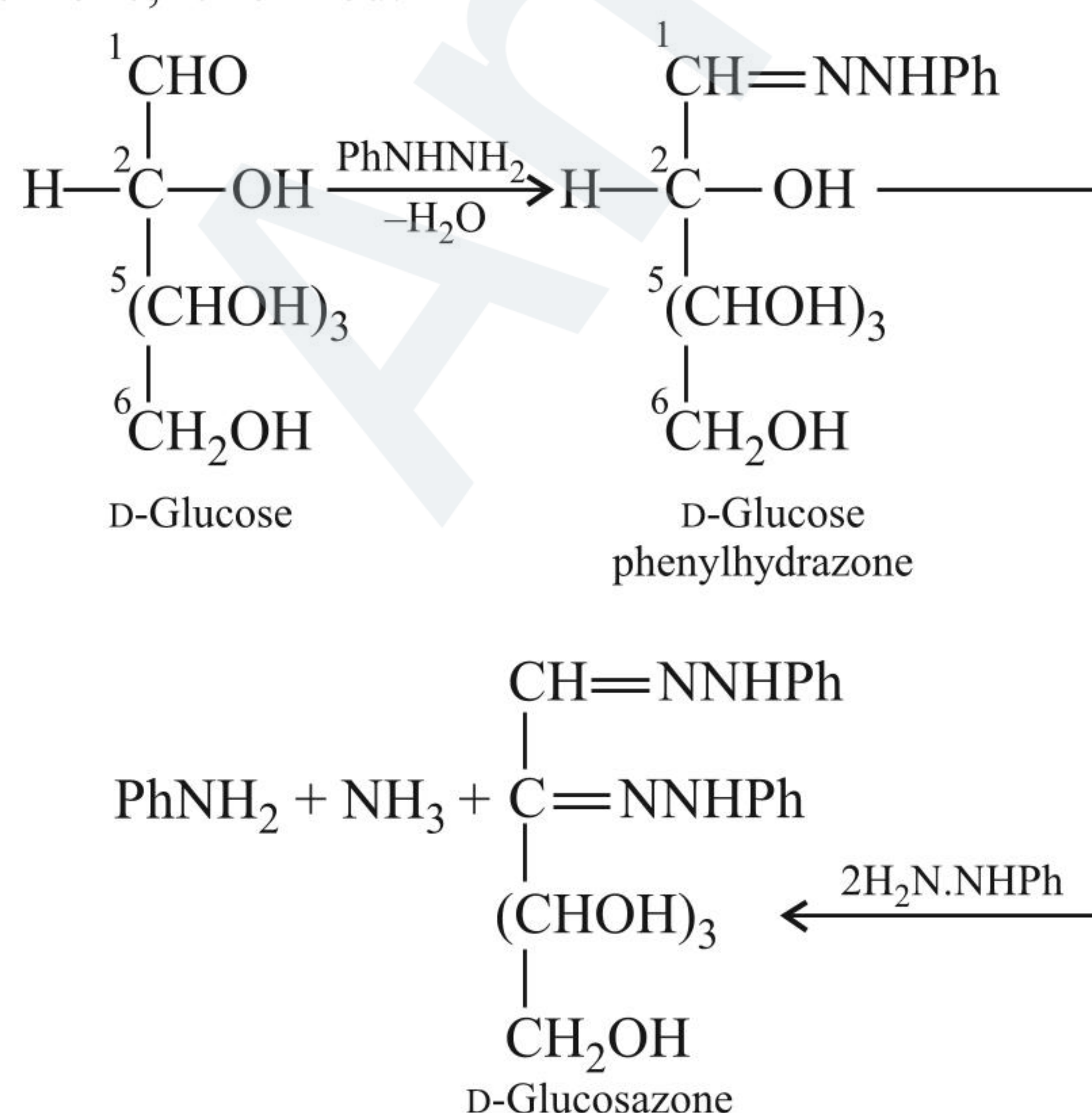
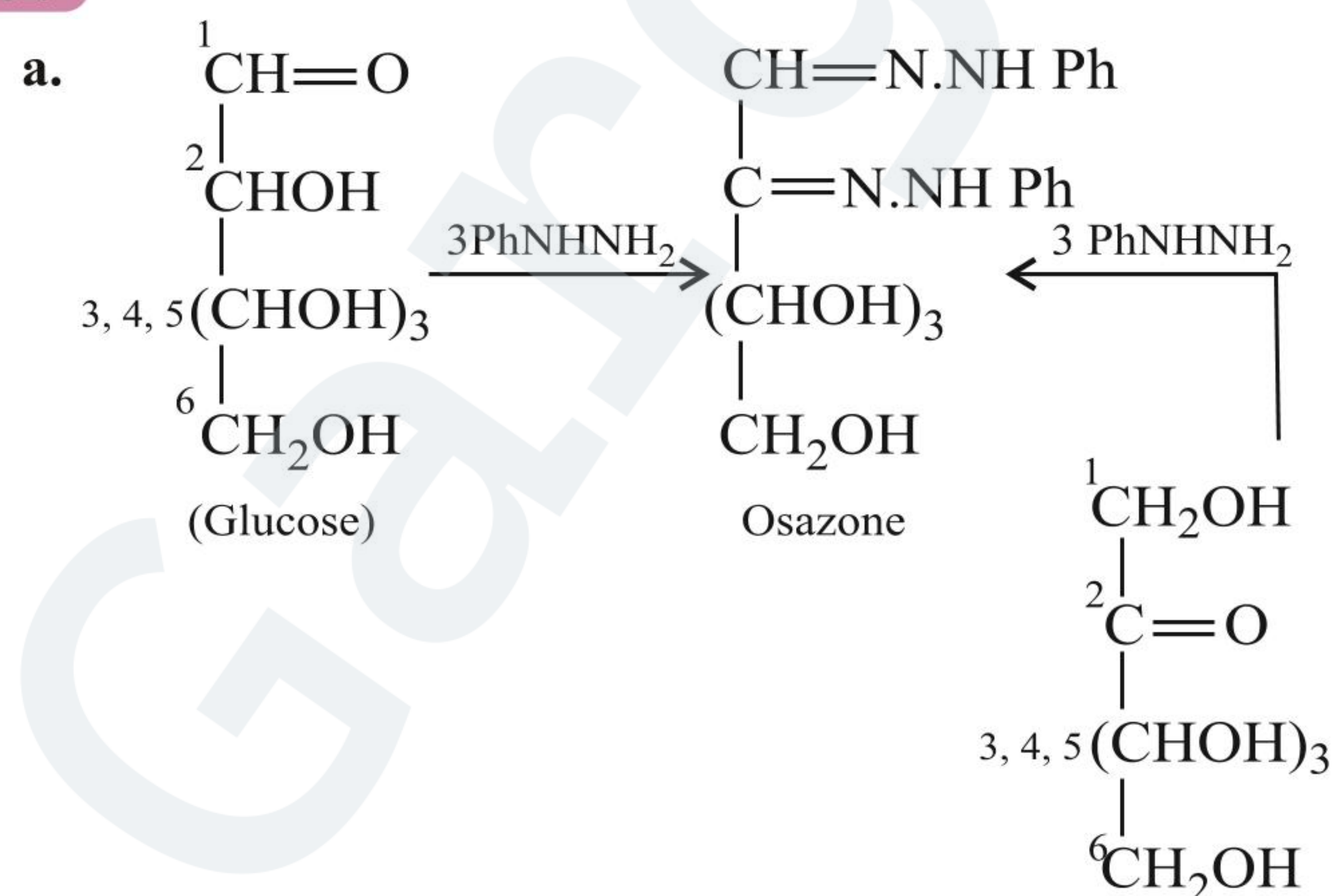


ILLUSTRATION 9.5

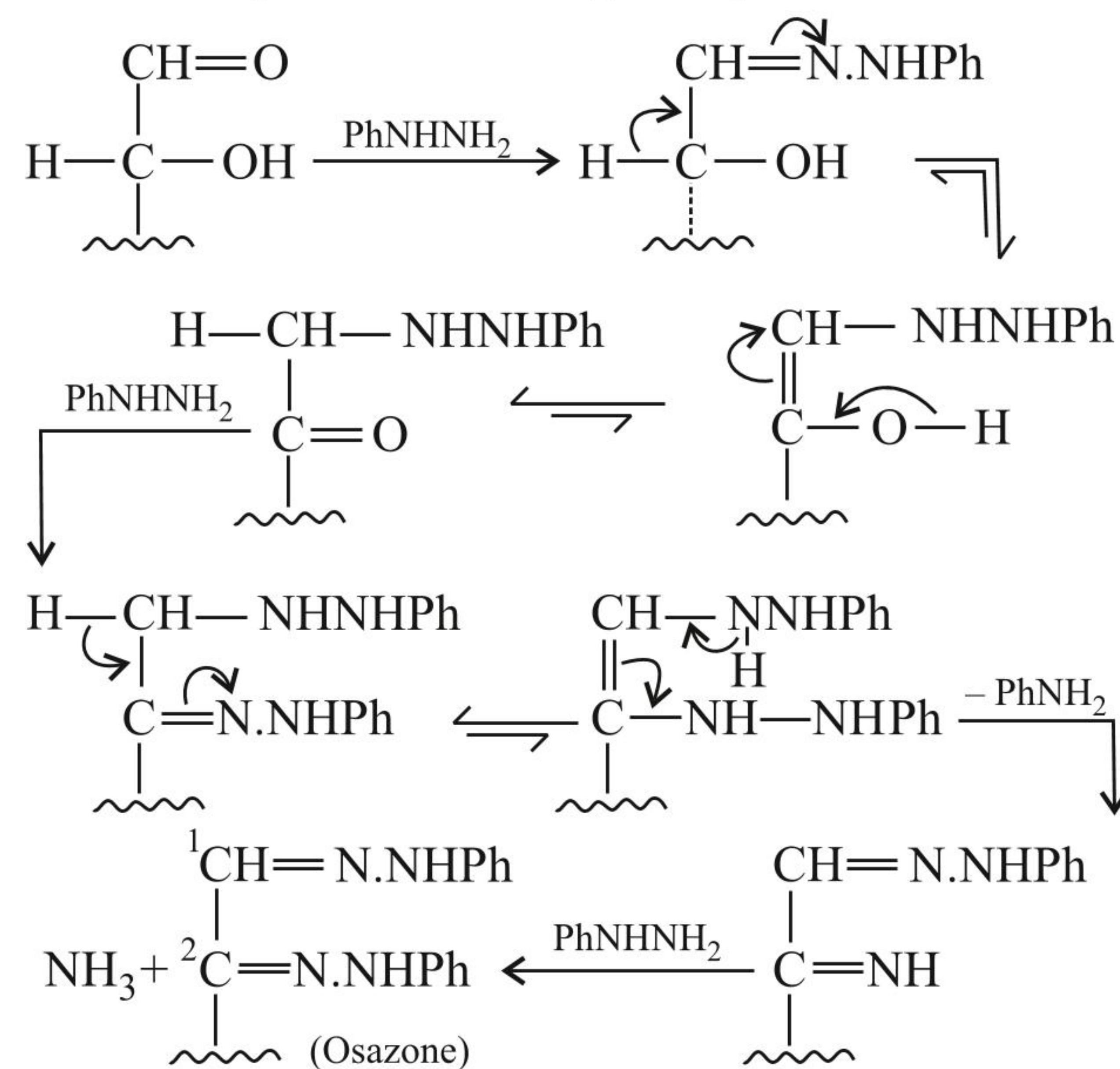
- a. Glucose and fructose form the same osazone, what does it prove?
- b. Why more than 3 mol of PhNHNH₂ do not react with glucose and fructose and how does PhNHNH₂, which is a powerful reducing agent, act as an oxidising agent in this case?

Sol.



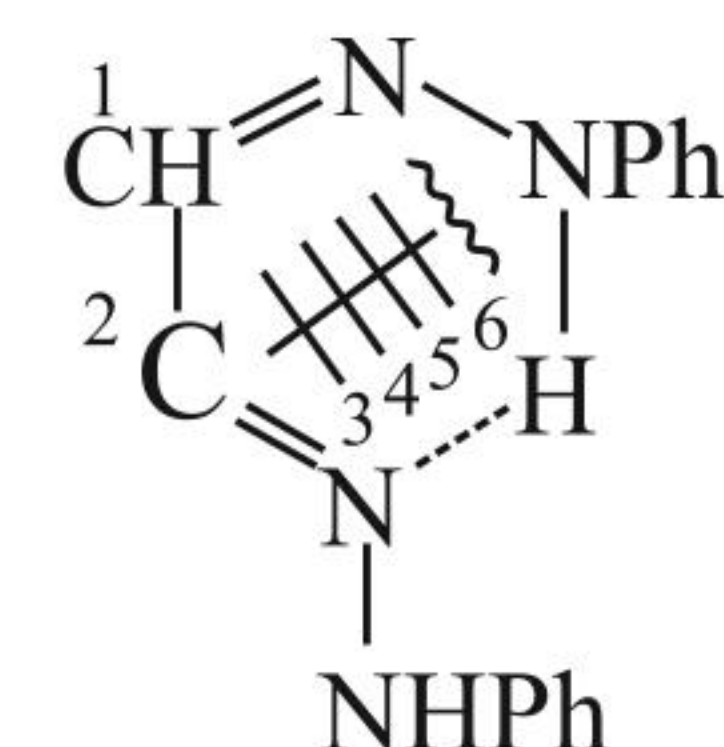
Glucose and fructose form the same osazone which proves that the configuration of OH group or stereochemistry at C-3, C-4, C-5, and C-6 in glucose and fructose is same.

- b. Mechanism: (Amadori rearrangement)



In the above mechanism, we find that PhNHNH₂ does not act as an oxidising agent.

The reaction takes place only up to two C atoms because the intermediate osazone formed can be stabilised by intra molecular H-bonding between N and H by forming a six-membered ring as shown below.



$$\text{D-Glucose} \xrightleftharpoons{\quad} \text{D-Mannose} \xrightleftharpoons{\quad} \text{D-Fructose}$$

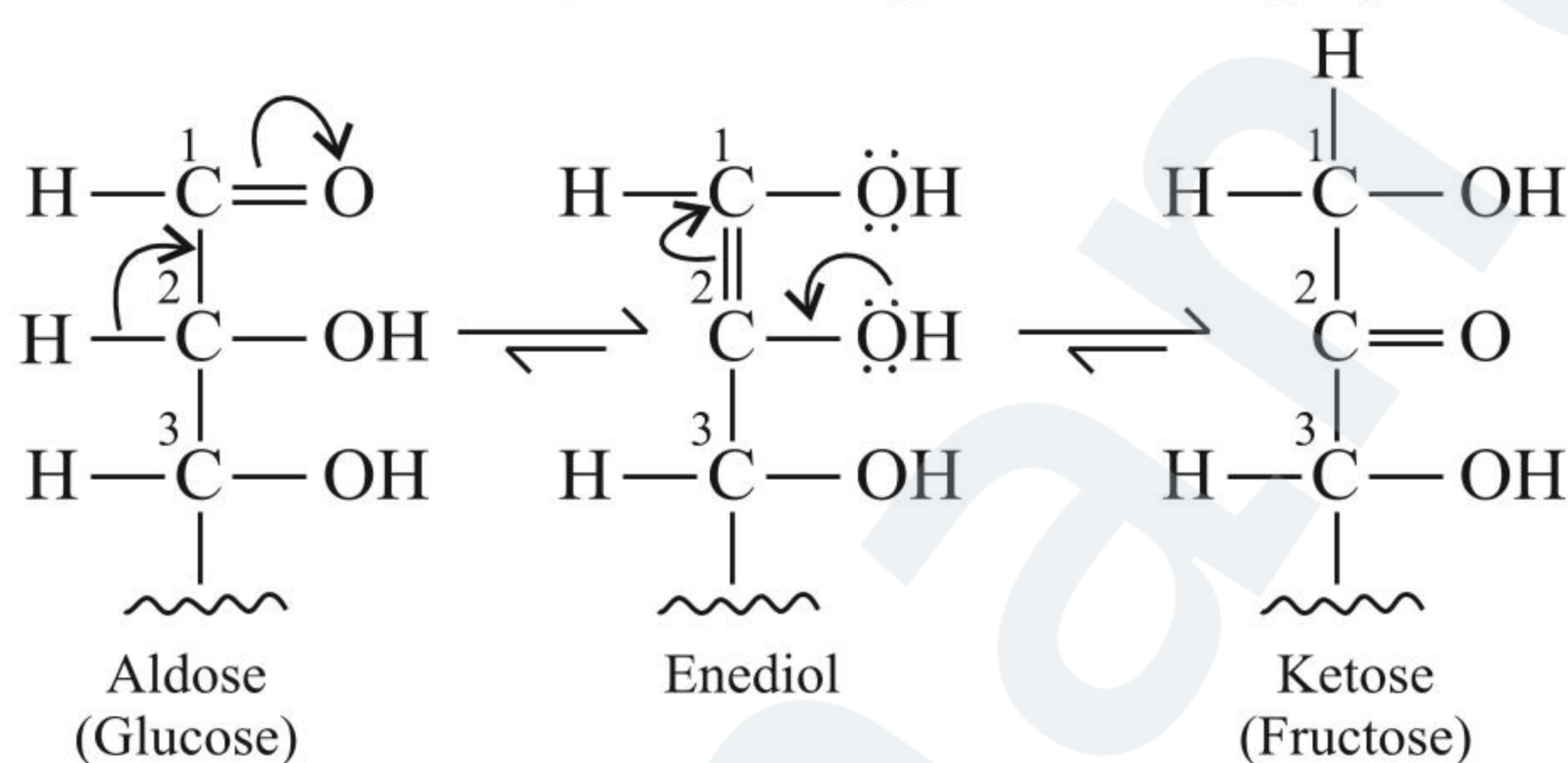
$$\begin{array}{c}
 \text{CHO} \\
 | \\
 \text{H} - \text{C} - \text{OH} \\
 | \\
 \text{HO} - \text{C} - \text{H} \\
 | \\
 \text{H} - \text{C} - \text{OH} \\
 | \\
 \text{H} - \text{C} - \text{OH} \\
 | \\
 \text{CH}_2\text{OH}
 \end{array}$$

$$\begin{array}{c}
 \text{CHO} \\
 | \\
 \text{HO} - \text{C} - \text{H} \\
 | \\
 \text{H} - \text{C} - \text{OH} \\
 | \\
 \text{HO} - \text{C} - \text{H} \\
 | \\
 \text{HO} - \text{C} - \text{H} \\
 | \\
 \text{CH}_2\text{OH}
 \end{array}$$

L(−) Glucose

9.3.12 LOBRY DE BRUYN VAN EKENSTEIN REARRANGEMENT REACTION

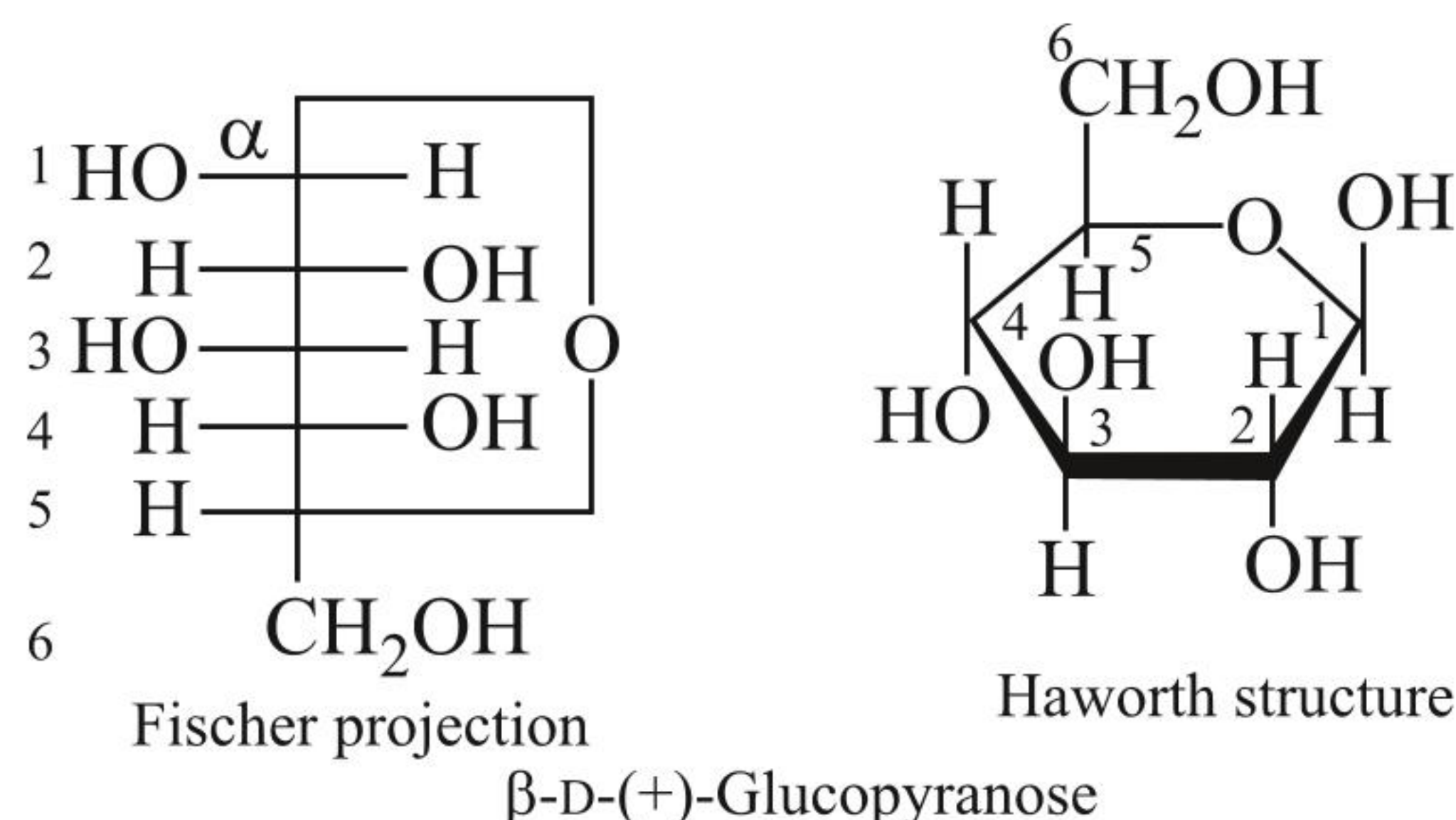
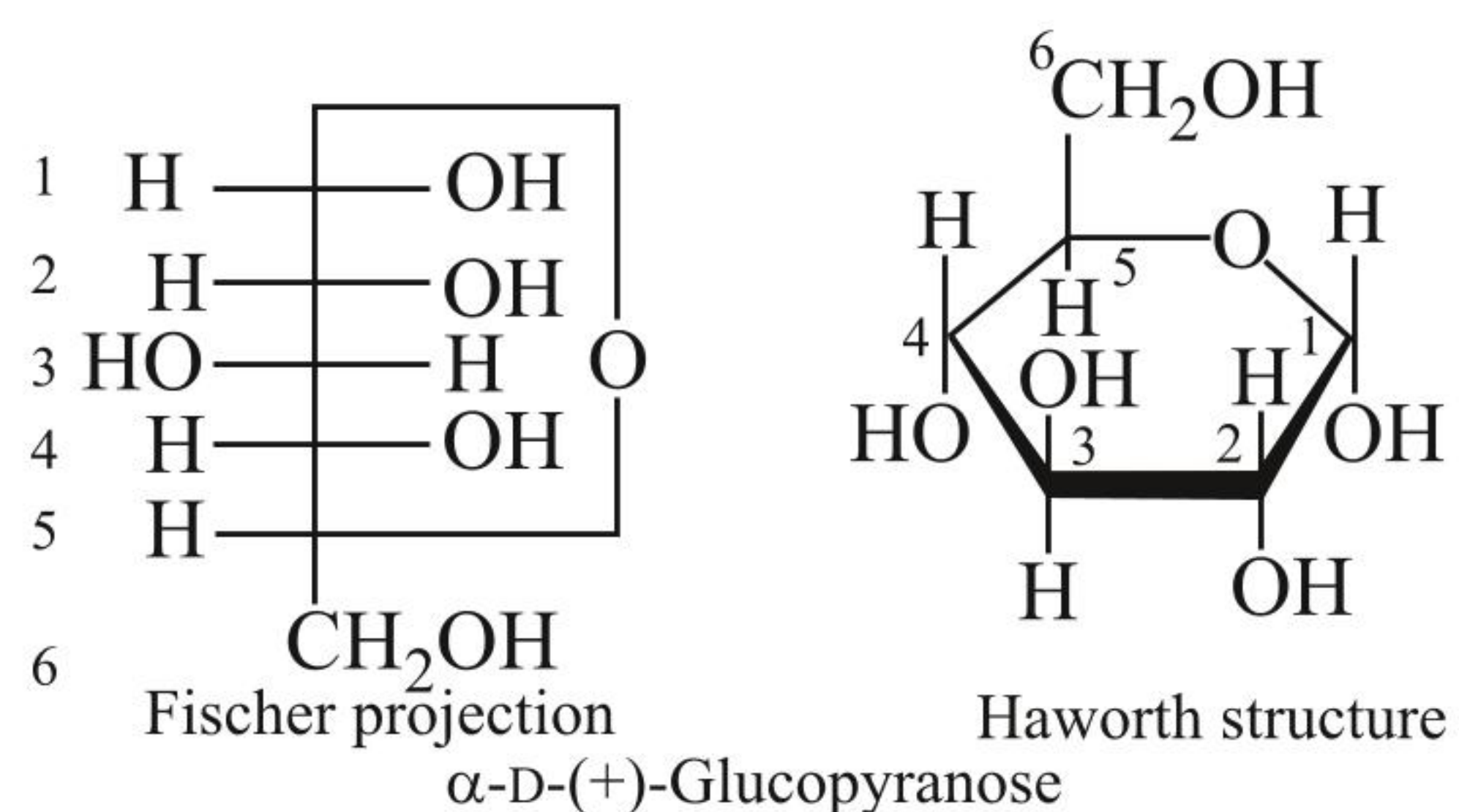
a. The ketose and aldose tautomerise in OH^- to a common intermediate enediol, establishing the following equilibrium:


$$\begin{array}{ccccc}
 \text{H}-\text{C}-\text{OH} & & \text{H}-\text{C}=\text{O} & & \text{H}-\text{C}=\text{O} \\
 \parallel & & | & & | \\
 \text{C}-\text{OH} & \rightleftharpoons & \text{H}-\text{C}-\text{OH} & + & \text{HO}-\text{C}-\text{H} \\
 | & & | & & | \\
 \text{~~~~~} & & \text{~~~~~} & & \text{~~~~~} \\
 \text{Enediol} & & \text{Glucose} & & \text{Mannose} \\
 & & \text{(C}^2 \text{ epimeric aldoses)} & &
 \end{array}$$
$$\alpha\text{-D-(+)} \rightleftharpoons \text{Equilibrium} \rightleftharpoons \beta\text{-D (+)} \text{ Glucose}$$

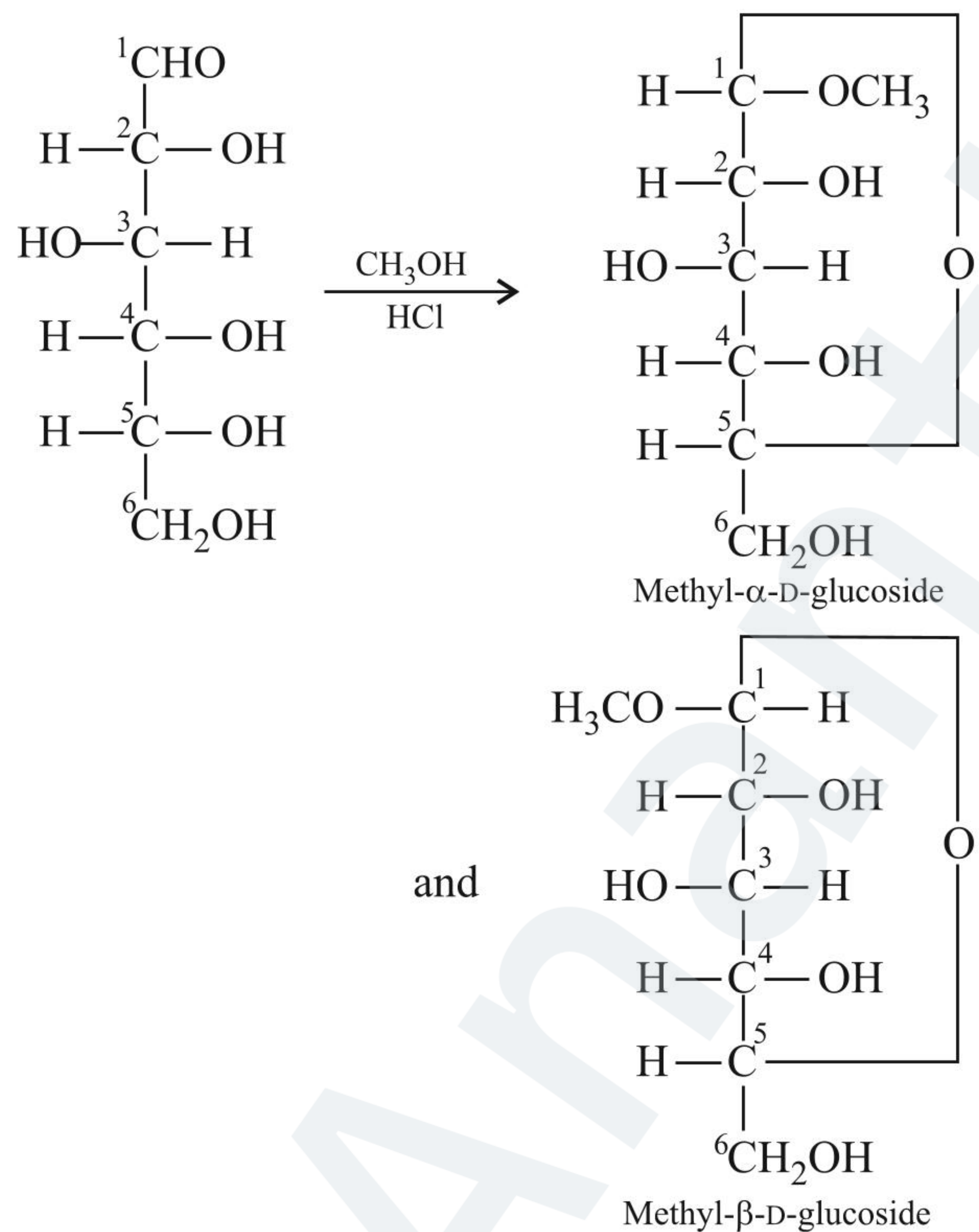
Glucose Mixture
+ 52.5°


Pyran


Furan

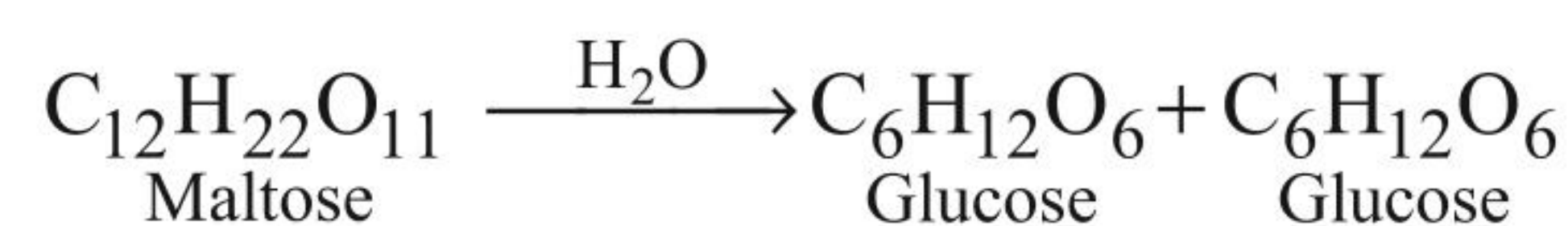
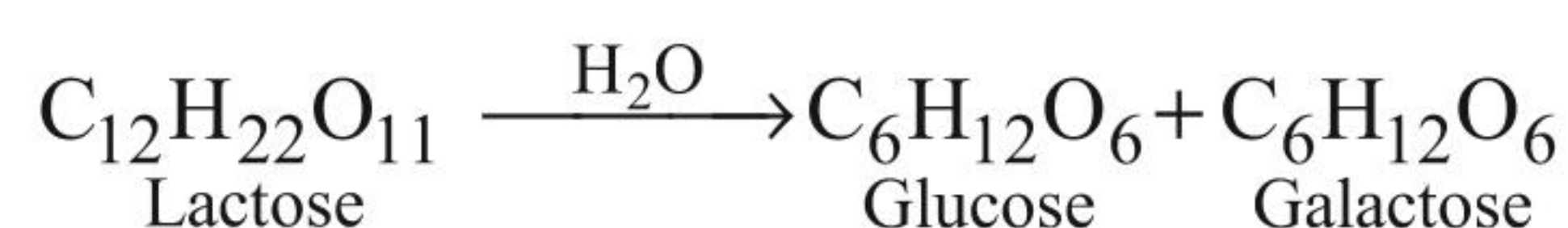
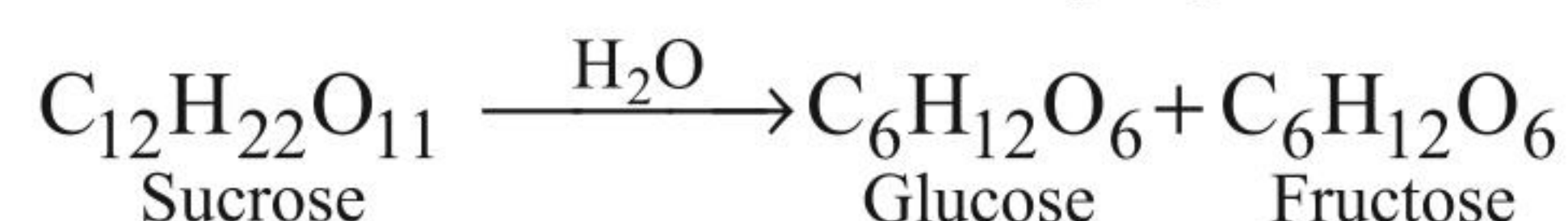


The thickened edge on the lower part of the ring in Haworth structure is closest to the viewer. The groups projecting to the right in Fischer projection are shown below the plane of the ring in Haworth structure, whereas those on the left are mentioned above the plane of the ring.



9.3.14 DISACCHARIDES

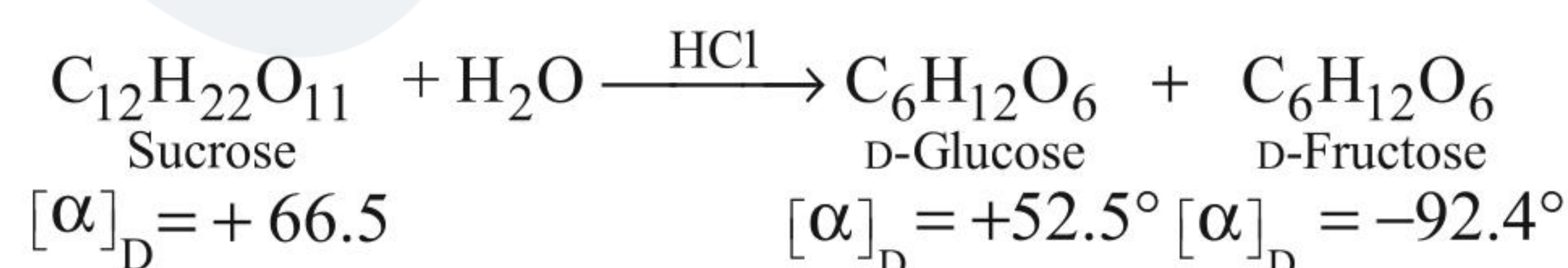
The disaccharides consist of two molecules of monosaccharides. When hydrolysed with enzymes or dilute acids, they give two molecules of either same or varying monosaccharides, e.g.,



On the basis of the position of linkages between the two monosaccharide units, the disaccharides might be reducing or nonreducing in nature. The resultant disaccharide is non-reducing, e.g., sucrose, when this glycosidic linkage involves the carbonyl functions of both monosaccharide units. On the other hand, the resulting disaccharide is the reducing sugar, e.g., maltose and lactose, if one of the carbonyl functions in either of the monosaccharide units is free.

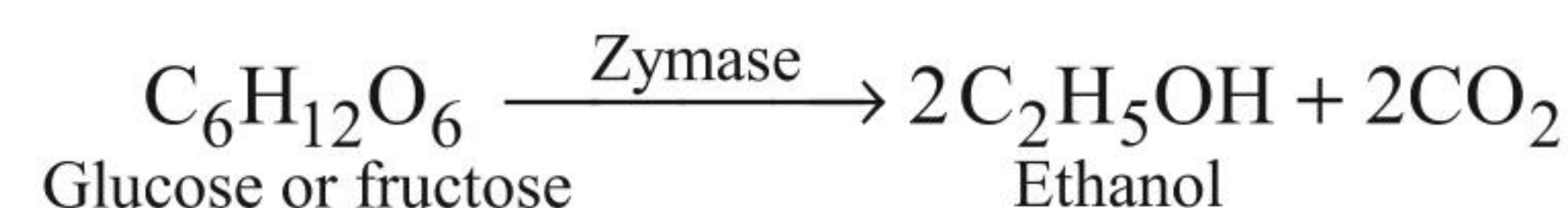
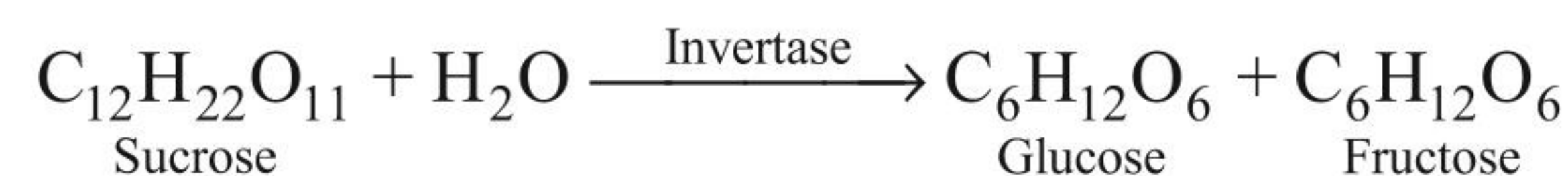
9.3.15 SUCROSE/CANE SUGAR (C₁₂H₂₂O₁₁)

It is the commonest disaccharide extensively distributed in plants. Industrially, it is prepared either from sugarcane or beet root. It is a crystalline, colourless, sweet substance which is soluble in water, and its aqueous solution is dextrorotatory, $[\alpha]_D = +66.5^\circ$. When hydrolysed with enzyme invertase or dilute acids, it forms the equimolar mixture of D-(+)-glucose and D-(-)-fructose.

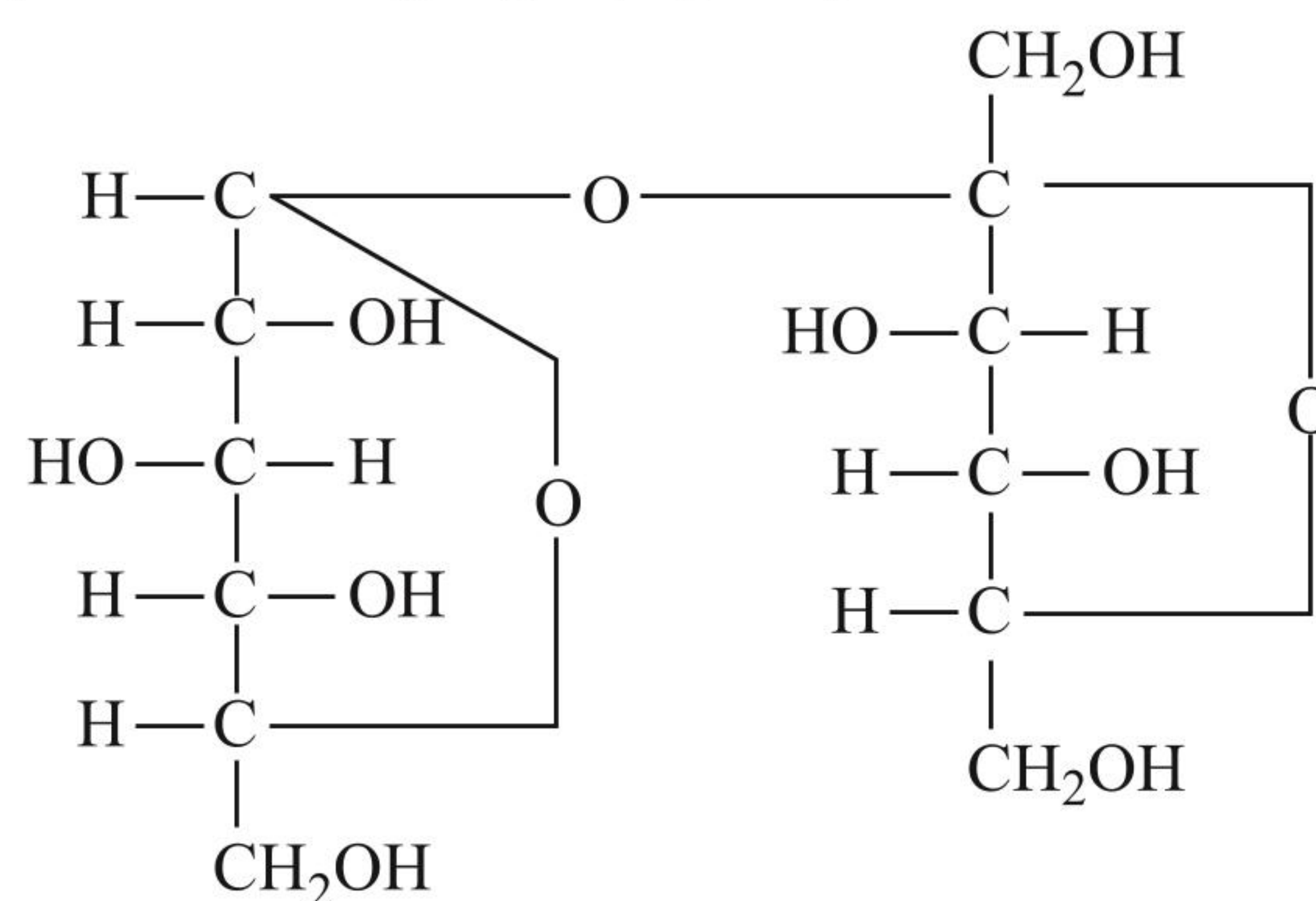


Sucrose is dextrorotatory but on hydrolysis forms dextrorotatory glucose and laevorotatory fructose. The mixture is laevorotatory because the laevorotation of fructose (-92.4°) is higher than dextrorotation of glucose ($+52.5^\circ$). So, on the hydrolysis of sucrose there is a change in the rotation sign from dextro (+) to laevo (-). This change is called **inversion** and the mixture is termed as **invert sugar**.

On the fermentation of sucrose solution by yeast, the enzyme invertase hydrolyses sucrose to glucose and fructose; enzyme zymase changes these monosaccharides to ethyl alcohol.



Haworth (1927) recommended the below given structure for sucrose, a non-reducing sugar (Fig. 9.2).



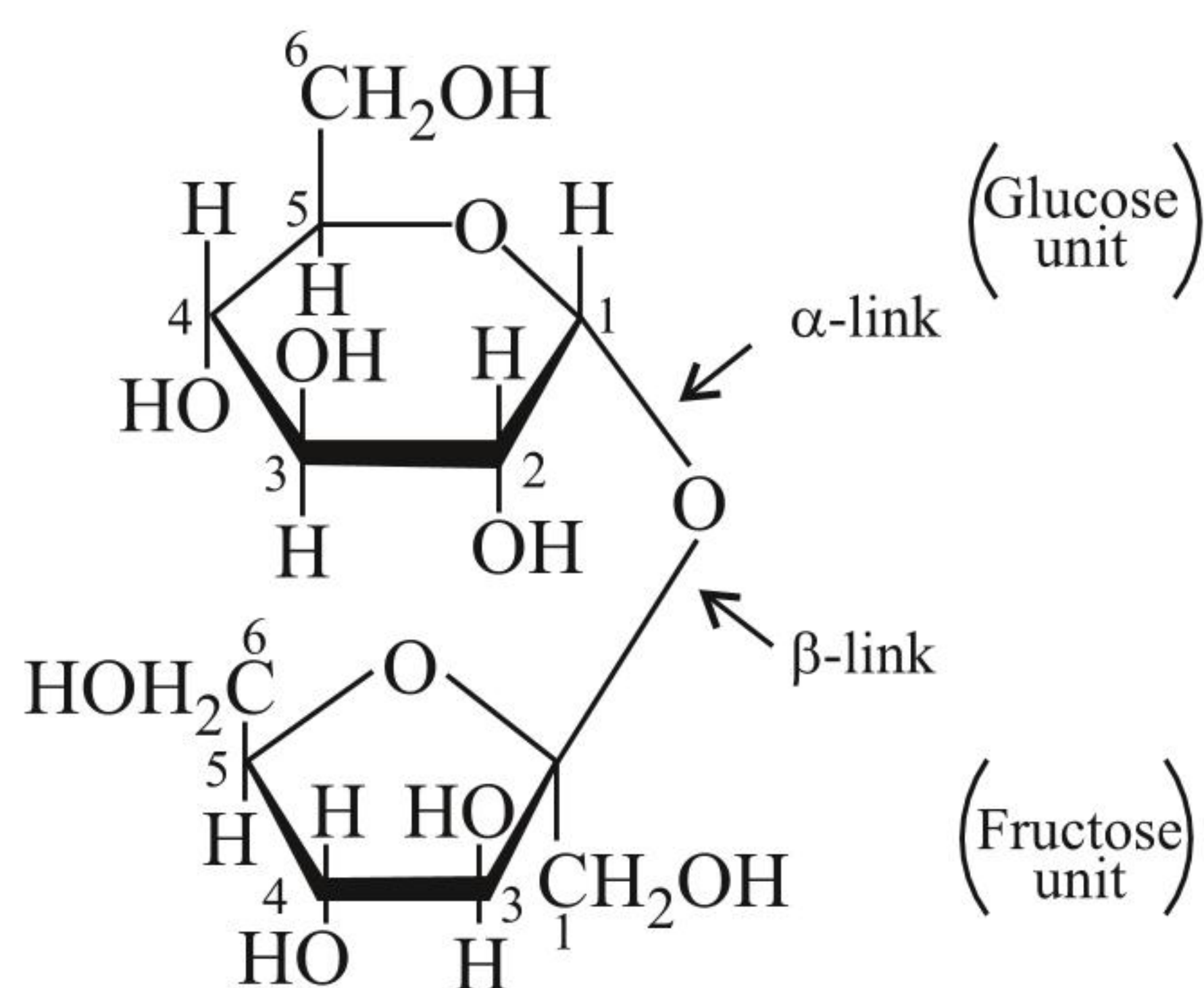
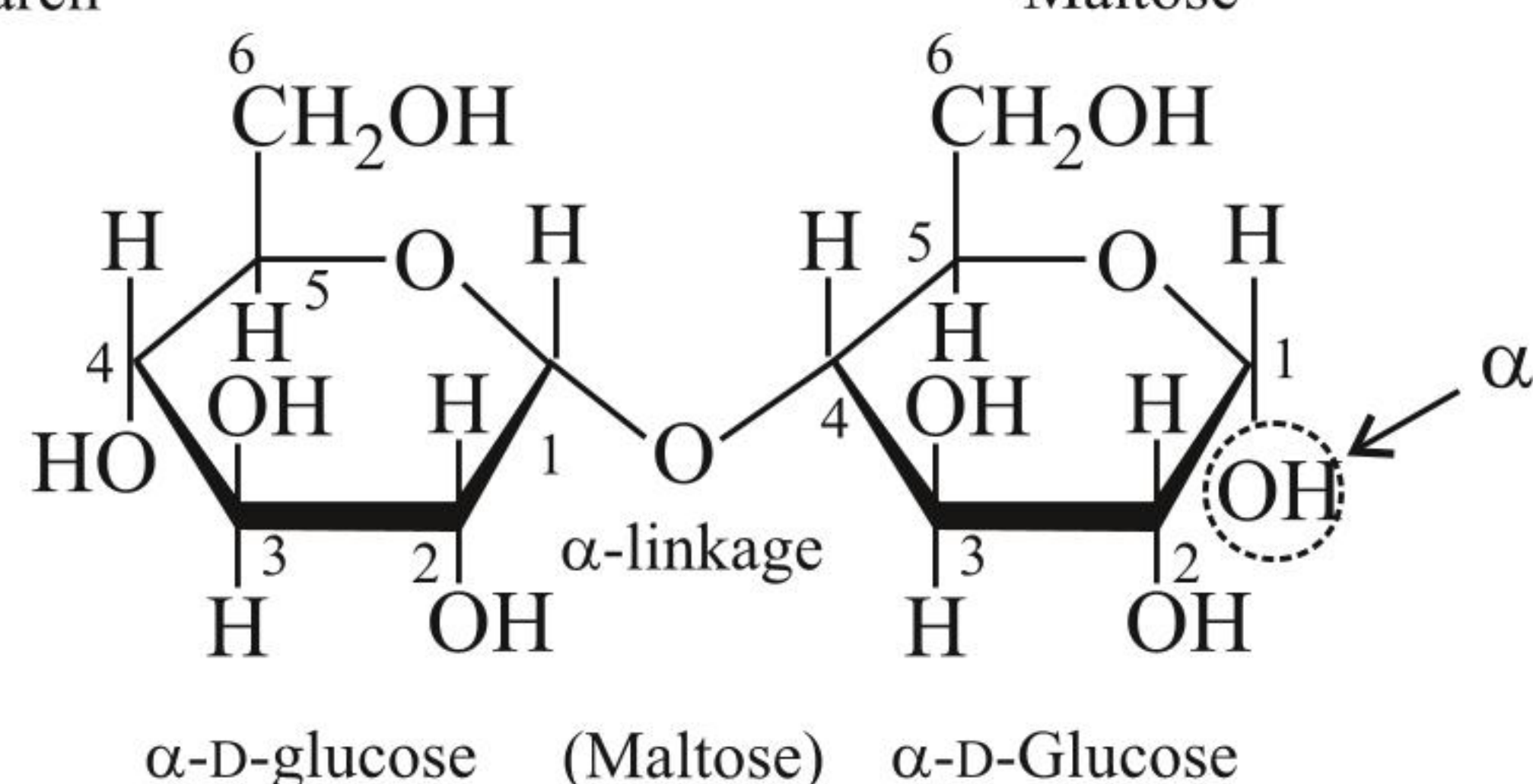
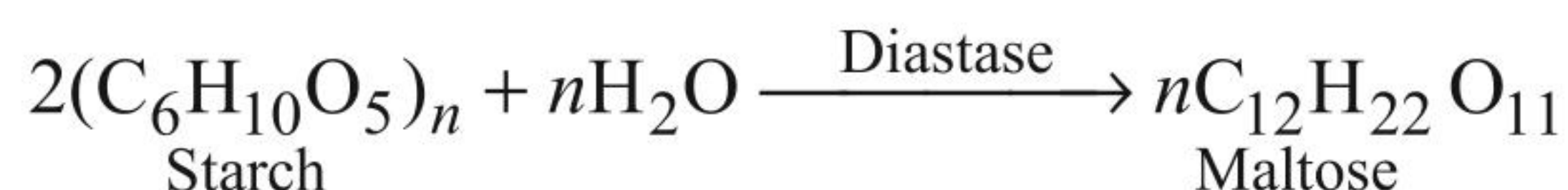


Fig. 9.2 Haworth's representation of sucrose

9.3.16 MALTOSE (MALT SUGAR, $C_{12}H_{22}O_{11}$)

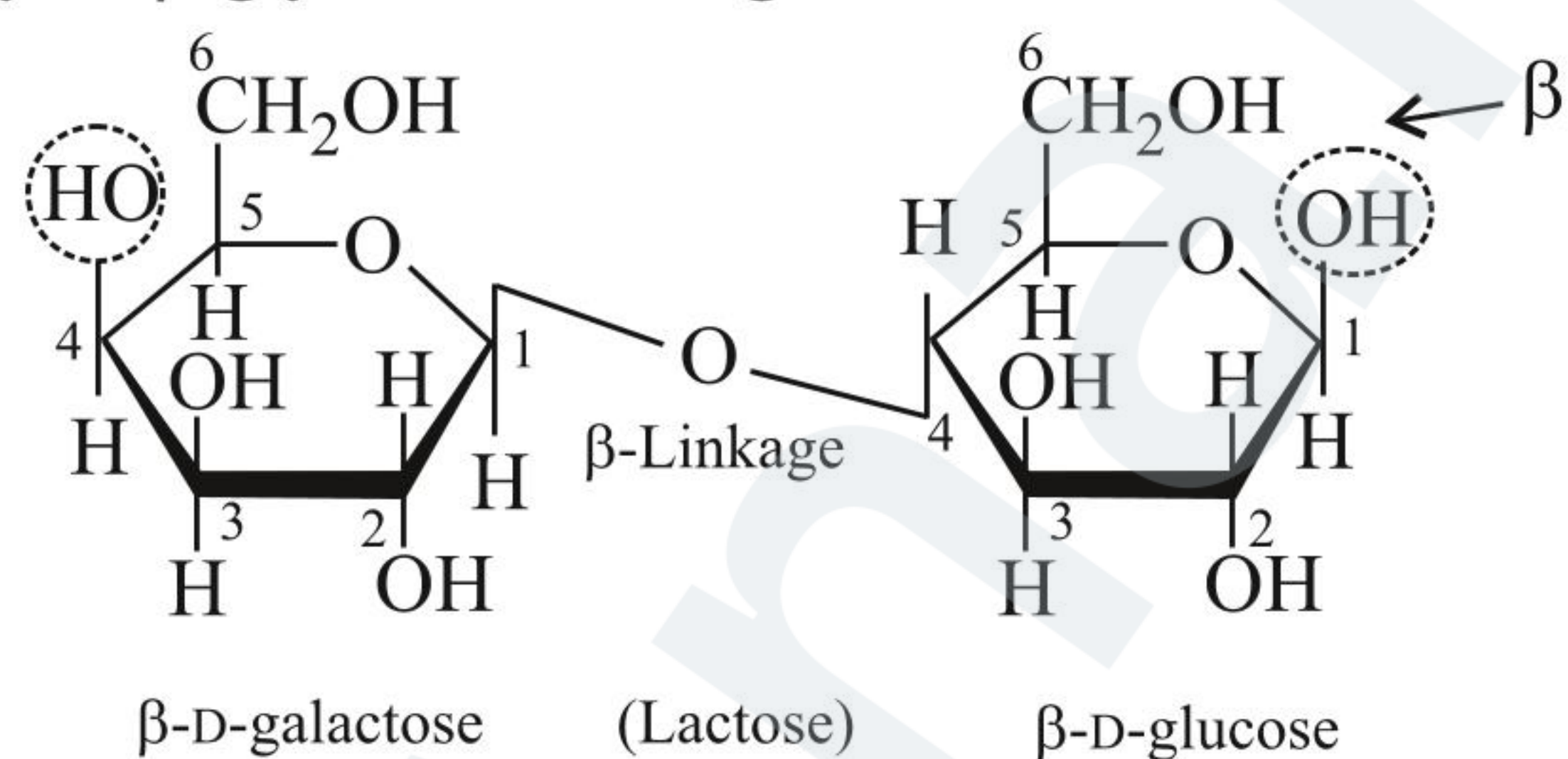
It is prepared by the fractional hydrolysis of starch by diastase, an enzyme available in malt (sprouted barley seeds).



On hydrolysis, 1 mol of maltose gives 2 mol of D-glucose. It is a reducing sugar in which two glucose units are connected through a α -glycosidic linkage between C-1 of one unit and the C-4 of the other and both these glucose units are in pyranose form.

9.3.17 LACTOSE (C₁₂H₂₂O₁₁)

Lactose is found in milk and is also known as milk sugar. On hydrolysis with dilute acid, it yields an equimolar mixture of D-glucose and D-galactose. It is a reducing sugar and gets **hydrolysed by emulsin, which is an enzyme that specifically hydrolyses β -glycosidic linkages.**



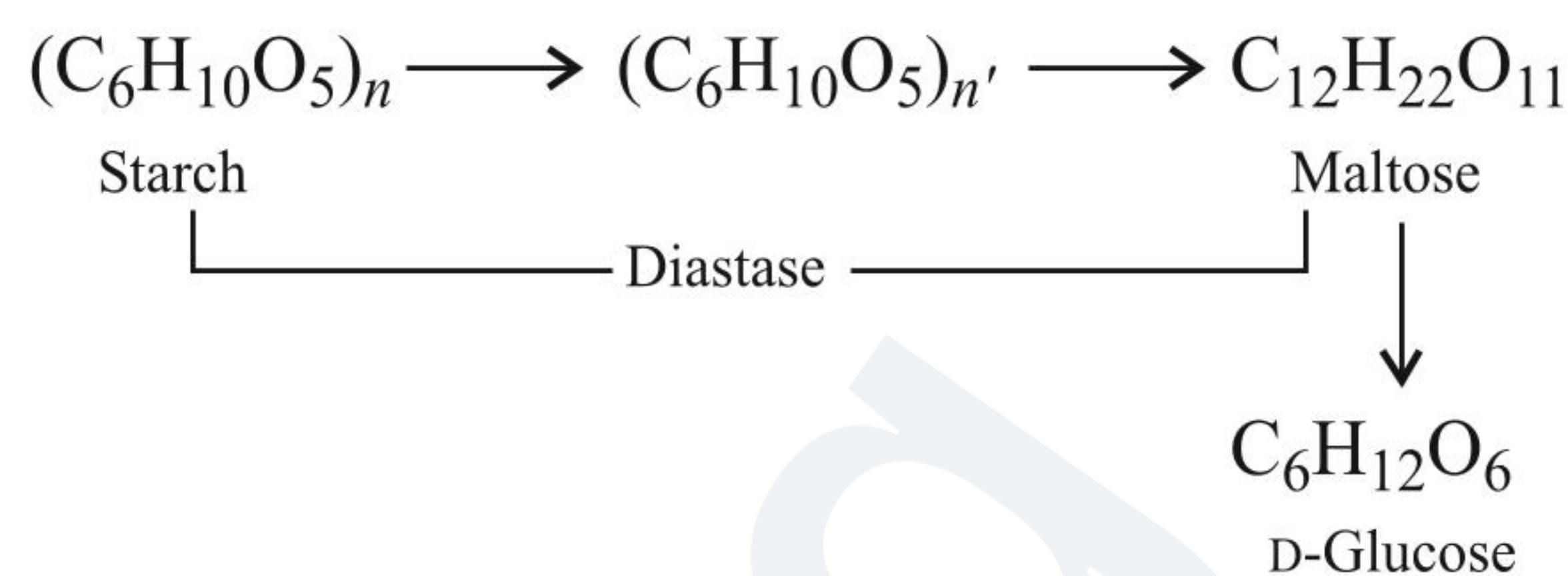
9.3.18 POLYSACCHARIDES

Polysaccharides are the carbohydrates having hundreds or even thousands of monosaccharide units jointed together by glycosidic linkages, e.g., starch, cellulose, glycogen, and dextrans. However, starch and cellulose are the most important polysaccharides.

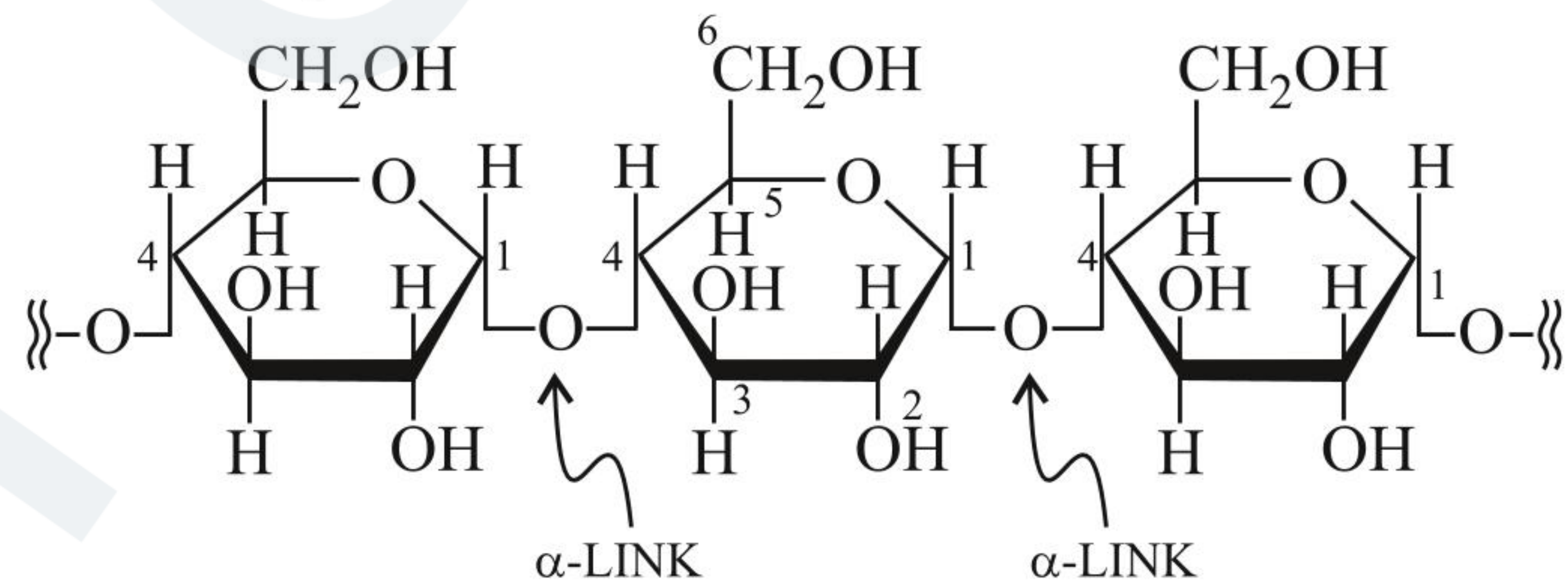
9.3.19 STARCH/AMYLUM (C₆H₁₀O₅)_n

Starch is found in all plants and specifically in their seeds. The main sources of starch are maize, wheat, potatoes, rice, barley, and sorghum. Starch is found in the form of granules that vary in size and shape according on their source plant. It is a white amorphous powder which is insoluble in cold water. With iodine solution and water it gives a blue colour which disappears on

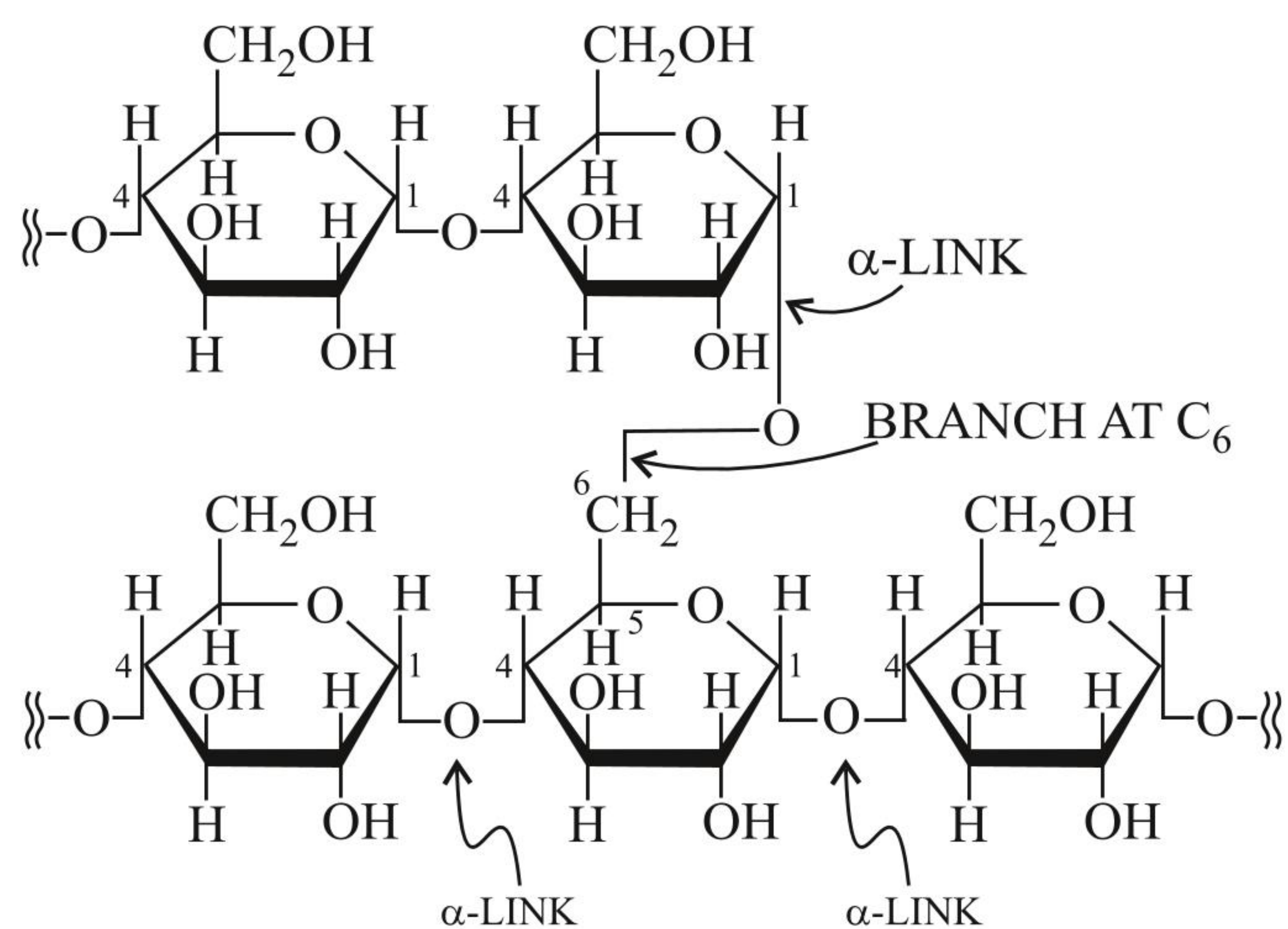
heating and reappears on cooling. If hydrolysed with dilute acids or enzyme, starch is broken down to molecules of variable complexity ($n > n$), maltose, and ultimately D-glucose.



Fehling's solution and Tollens reagent are not reduced by starch. Also, it does not form an osazone, implying that all hemiacetal hydroxyl groups of the glucose units (C-1) are linked with glycosidic linkages. Starch is basically a mixture of two polysaccharides: amylose and amylopectin. Natural starch is composed of about 10–20% of amylose and 90–80% of amylopectin. Amylose is water soluble and shows blue colour with iodine. It is a straight-chain polysaccharide possessing just D-glucose units combined by α -glycosidic linkages involving C-1 of one glucose and C-4 of the next. It can possess 100–3000 glucose units, i.e., its molecular mass can vary from 10,000 to 500,000.



Amylose



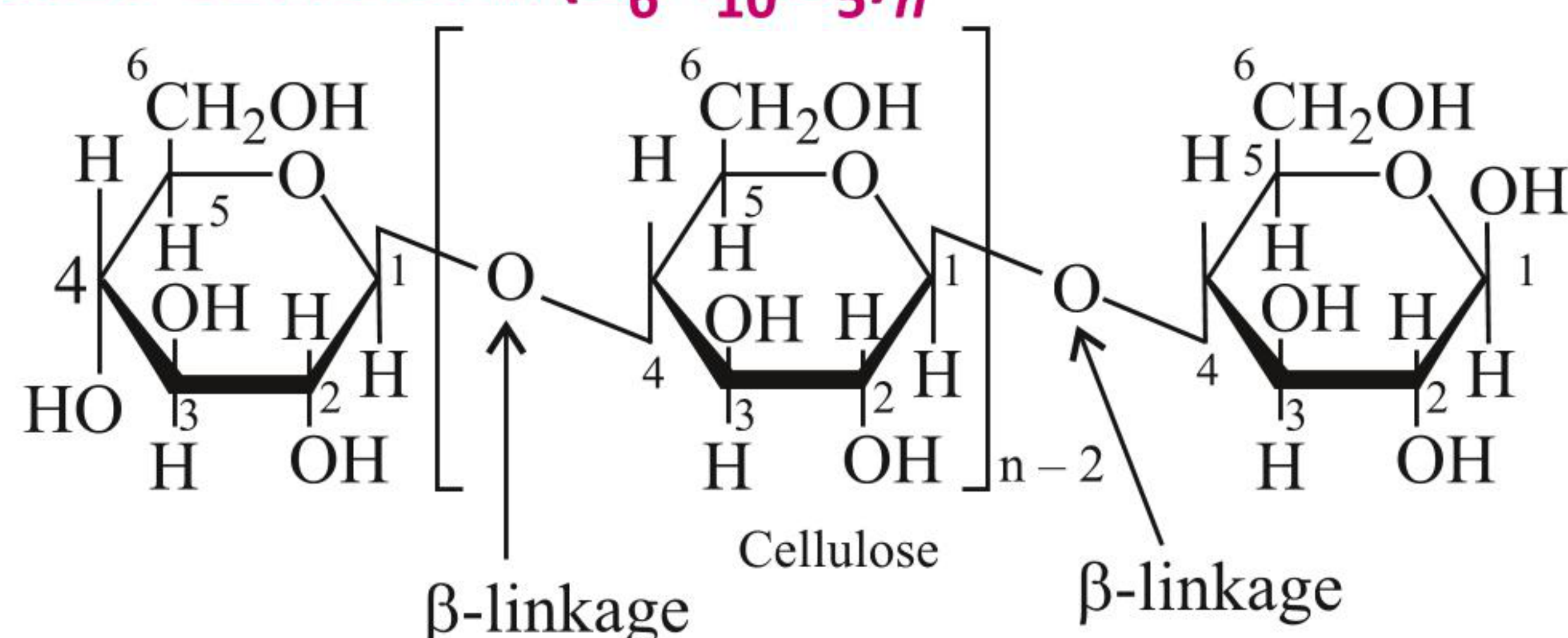
Amylopectin

Amylopectin is a branched-chain polysaccharide. It is insoluble in water and does not show blue colour with iodine. It comprises chains of 25–30 D-glucose units joined by α -D-glycosidic linkages between C-1 of one glucose unit and C-4 of the next glucose unit (like amylose). Nonetheless, these chains are linked to each other by 1, 6-linkages. Starch is an important food material for human beings and is hydrolysed by enzyme amylase which is found in saliva resulting in glucose as the end product which is an indispensable nutrient.

Glycogen (animal starch): A polysaccharide consisting of a highly branched polymer of glucose. It is the principal storage

form of carbohydrate energy and is found mainly in the liver and also in muscle cells. Glycogen is converted to glucose when the need arises.

9.3.20 CELLULOSE ($C_6H_{10}O_5$)_n



It is the major ingredient of the cell walls of plants. Wood has about 45–50%, while cotton possesses around 90–95% cellulose. It is a colourless amorphous solid decomposable on heating. It is mostly linear with the individual strands aligning with each other through multiple hydrogen bonds. This provides firmness to its structure. Due to this nature it is used effectively as a cell wall material.

It does not reduce Tollens reagent or Fehling's solution. Further, cellulose does not form osazone. It is not fermented by yeast and is not hydrolysed easily like starch. However, when heated with dilute sulphuric acid under pressure it gives D-glucose only.

Cellulose is a straight-chain polysaccharide comprising only D-glucose units. These units are joined through β -glycosidic linkages between C-1 of one glucose unit and C-4 of the next glucose unit. The molecular mass of cellulose falls in the range of 50,000–500,000 (300–2500 D-glucose units). It is used for manufacturing rayon and gun cotton.

A large number of cellulolytic bacteria in the stomach (rumen) of ruminant mammals such as cattle and sheep, breakdown cellulose using enzyme cellulase. Afterwards, it is digested and converted into glucose. But in case of human stomach, things are different because it does not possess enzyme capable of breaking cellulose molecules.

Note:

- β -glycosidic linkage is hydrolysed by emulsin enzyme
- α -glycosidic linkage is hydrolysed with amylase enzyme

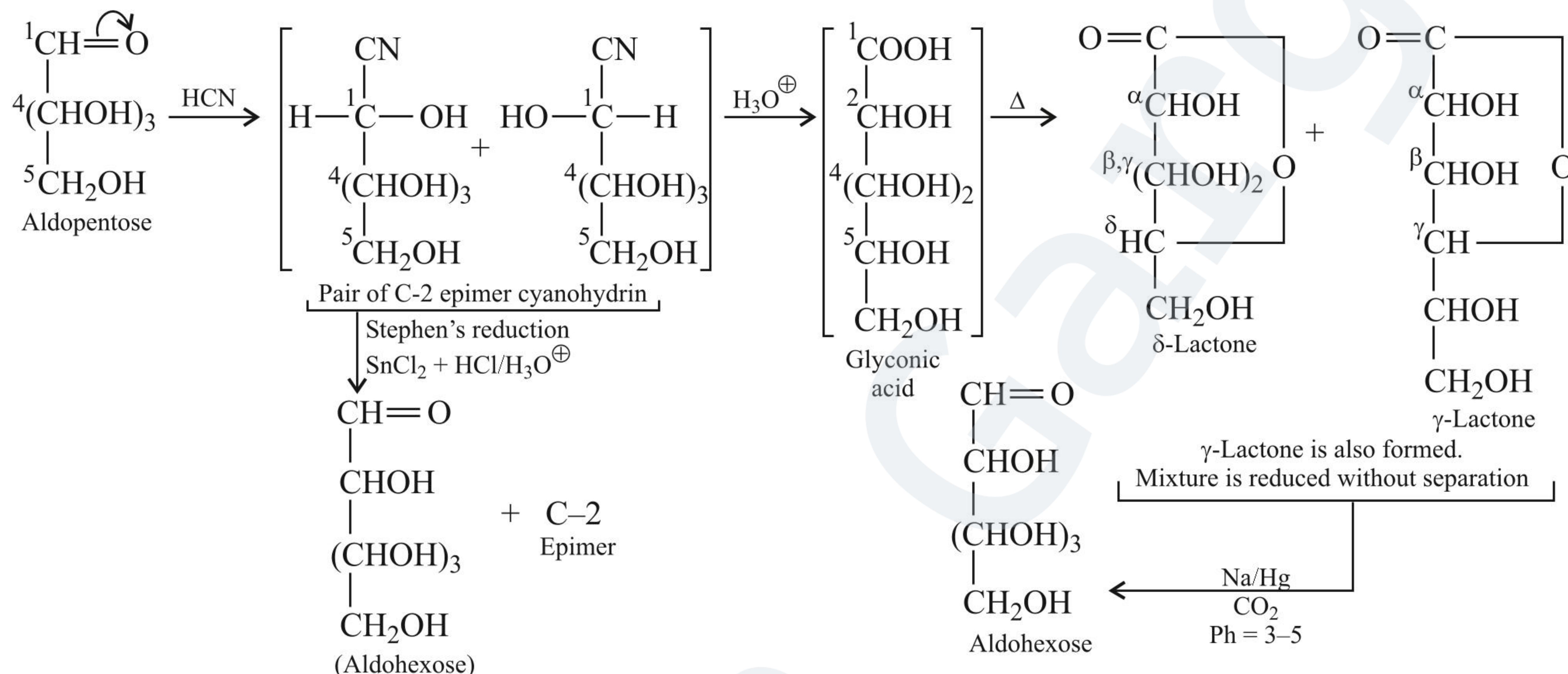
Table 9.1 Disaccharides and polysaccharides

S.No.	Disaccharide	Hydrolysis products	Linkage
1.	Sucrose $\xrightarrow[\text{or Invertase}]{H_3O^+}$ (Non-reducing sugar)	Glucose + Fructose Hydrolysed by both Amylase & emulsin	$C_1-\alpha$ (Glucose) (six-membered ring) $\longrightarrow$ $C_2-\beta$ (Fructose) (five-membered ring)
2.	Maltose $\xrightarrow[\text{or Maltase}]{H_3O^+}$ (Reducing sugar)	Glucose + Glucose Hydrolysed by Amylase	$(C_1-\alpha)$ (Glucose) $\longrightarrow$ C_4 of $(\alpha\text{-glucose})$ Free anomeric (C-1) (OH)
3.	Lactose $\xrightarrow[\text{or Lactase}]{H_3O^+}$ (Reducing sugar)	Galactose + Glucose Hydrolysed by emulsin	$(C_1-\beta)$ Galactose $\longrightarrow$ C_4 of $(\beta\text{-glucose})$ Free anomeric (C-1) (OH)
Polysaccharides:			
4.	Starch $\xrightarrow[\text{Amylase}]{H_3O^+}$ ($C_6H_{10}O_5$) _n ($n \approx 200-1000$) Chief food reserve material, found in seeds, roots, etc. (Non-reducing sugar)	n moles of glucose Amylose: — Glucose — Glucose — Glucose — $C_1(\alpha) \longrightarrow C_4 - C_1(\alpha) - C_4 - C_1(\alpha) -$ (Linear structure) Amylopectin: — Glucose — Glucose $C_1(\alpha) \longrightarrow C_4 \downarrow C_1(\alpha)$ $\downarrow$ C_6 — Glucose — Glucose — Glucose $C_1(\alpha) \longrightarrow C_4 \downarrow C_1(\alpha)$ $\downarrow$ C_6 — Glucose — Glucose — Glucose (Highly branched structure)	Amylose + Amylopectin (Linear polymer) (Branched polymer) (20%) (80%) Water soluble Water insoluble

5.	Cellulose ($C_6H_{10}O_5$)_n ($n \approx 1000 - 3000$) Chief constituent of cell walls of plants, cotton, wood, and jute. (Non-reducing sugar)	n moles of glucose — Glucose — Glucose — Glucose — $C_1(\beta) \longrightarrow C_4 \quad C_1(\beta) \longrightarrow C_4$ (Linear structure)
----	---	--

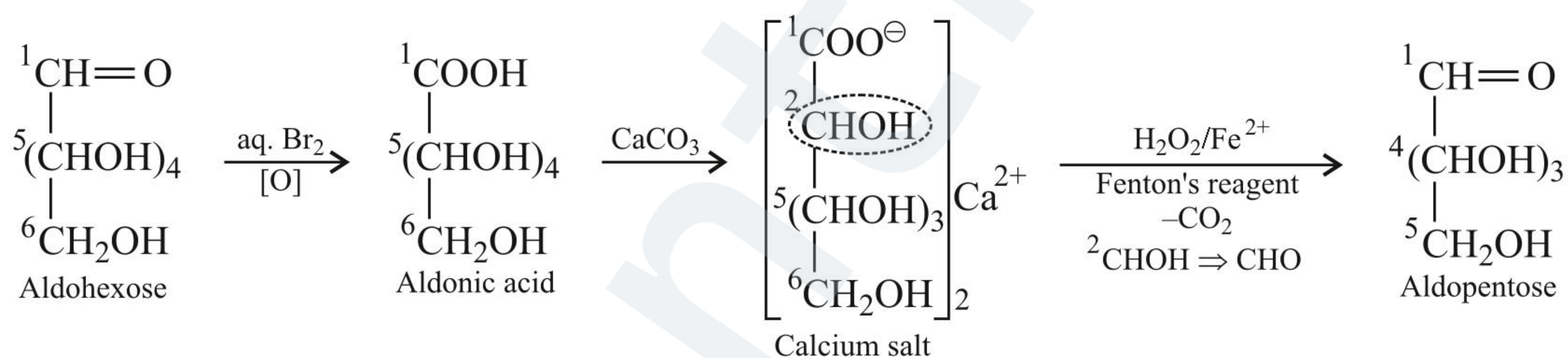
9.3.21 CONVERSION OF ALDOPENTOSE TO ALDOHEXOSE

(Kiliani-Fischer method)



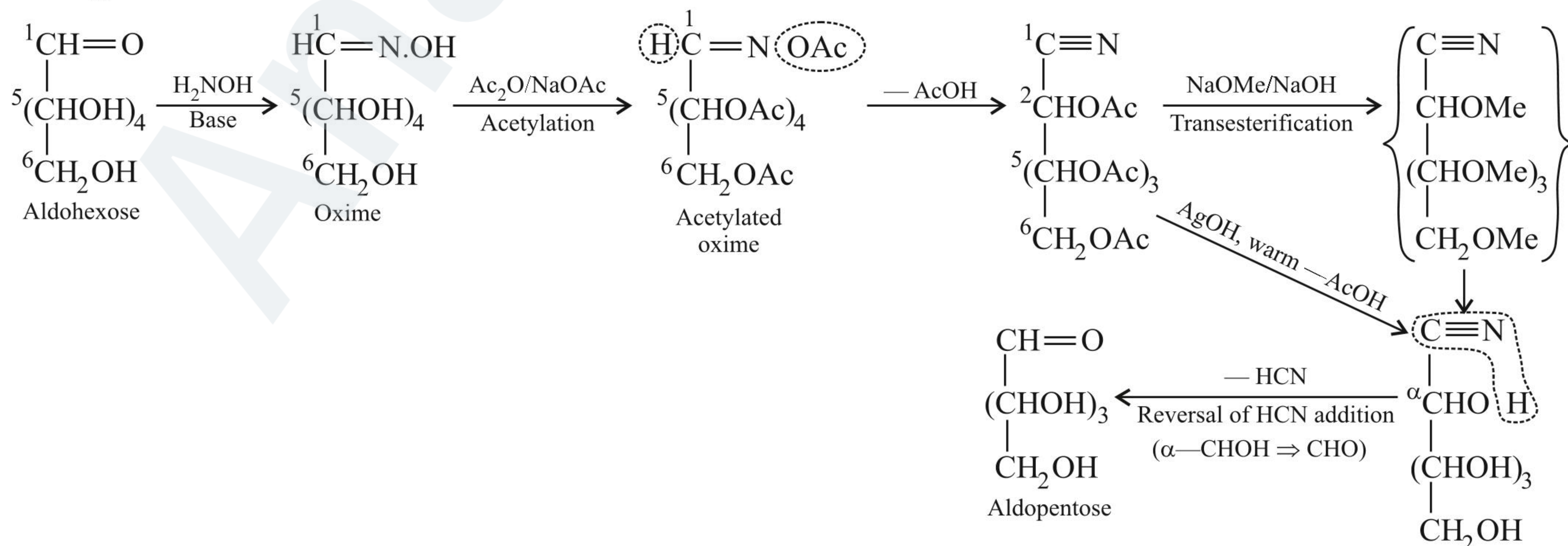
9.3.22 CONVERSION OF ALDOHEXOSE TO ALDOPENTOSE

a. (Ruff degradation) (Oxidative decarboxylation):



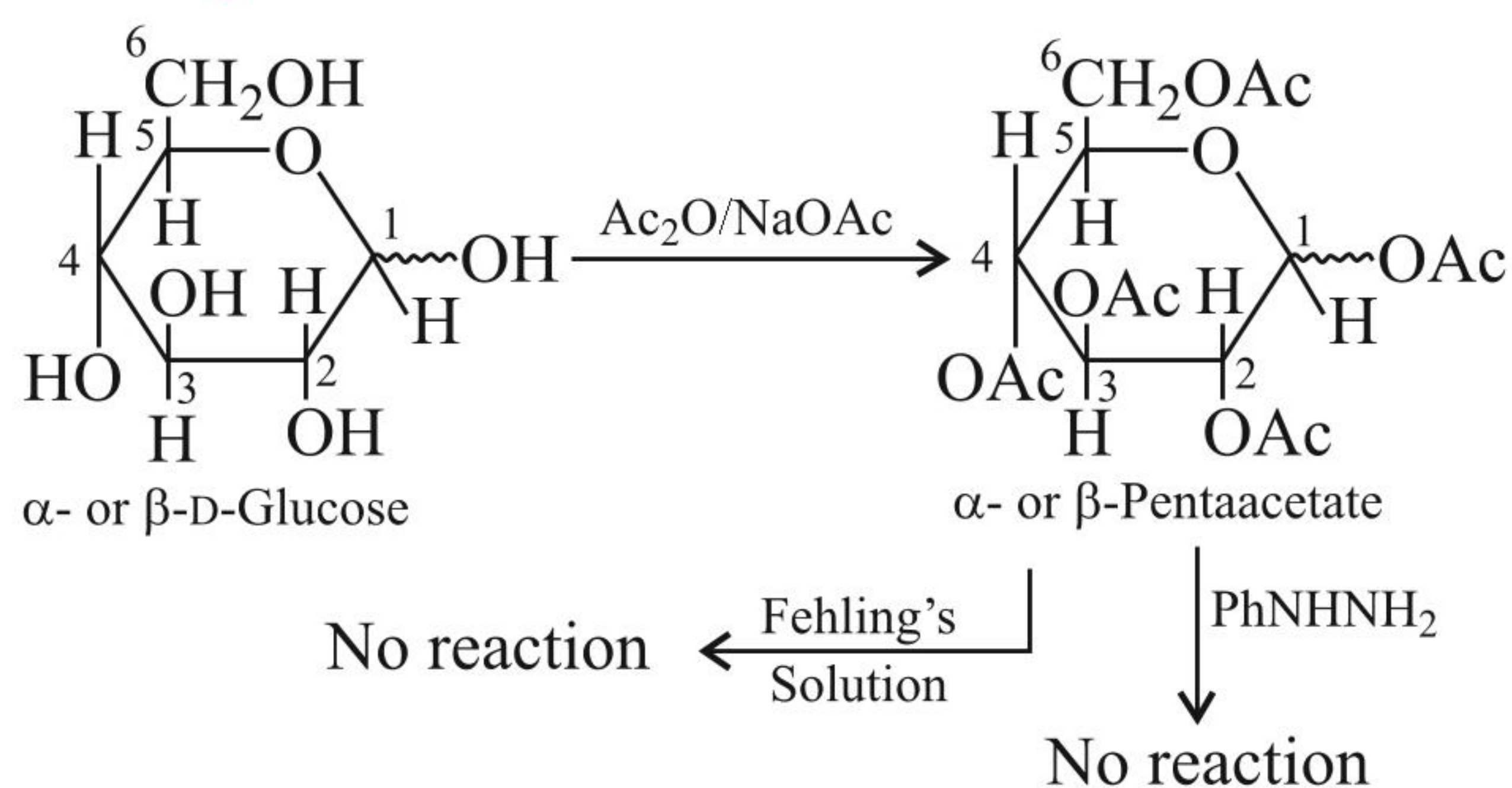
Here, α -CHOH or CHOH is oxidised to $(C=O)$ without any configurational changes of the other chiral C atom. No epimers are formed.

b. Wohl degradation:



Furthermore, α -CHOH or CHOH changes to $(CH=O)$ without any configurational changes of the other chiral C atoms. No epimers are formed.

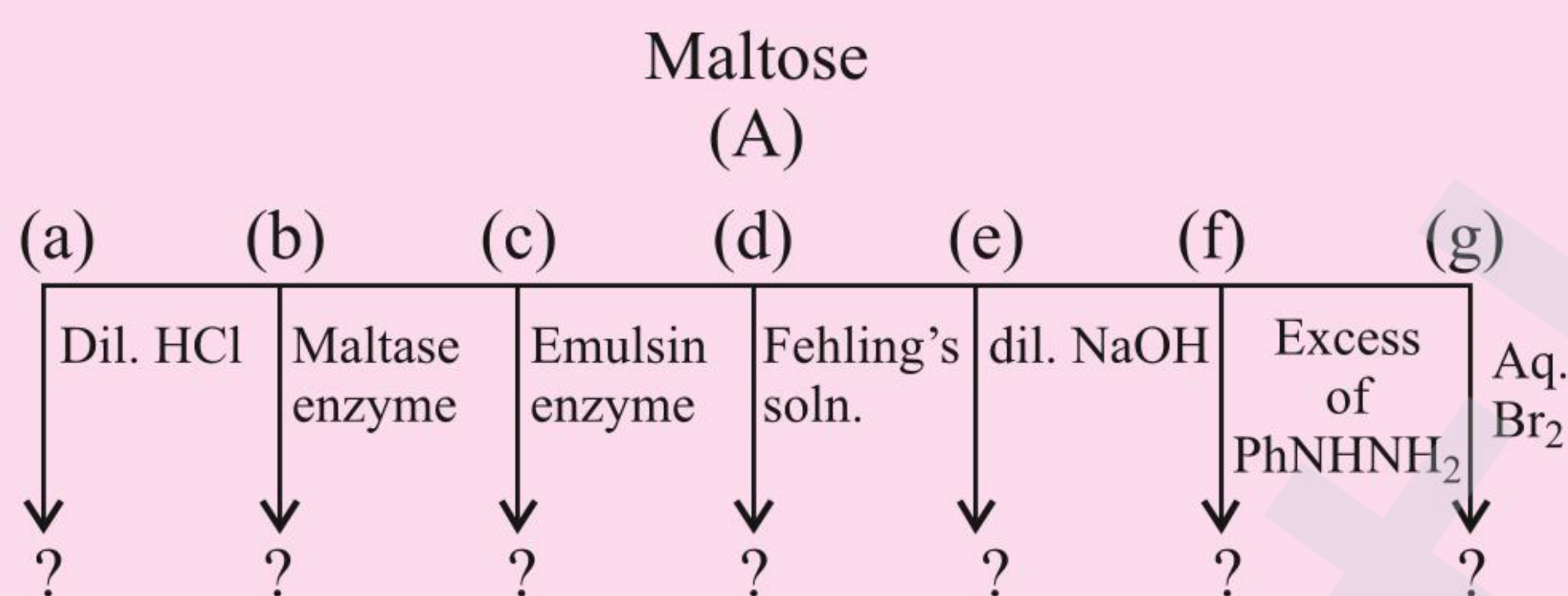
9.3.23 ACETYLATION OF ALDOHEXOSES WITH $\text{Ac}_2\text{O}/\text{NaOAc}$



The α - and β -pentaacetate of the hemiacetal are isolated not the pentaacetate of the aldehyde. The anomeric C-1 OH is acetylated; the OH that formed the ring is not available for acetylation. The pentaacetate does **not react with either PhNHNH_2 or Fehling's solution because they are not hydrolysed under the basic conditions of both the reagents, and thus CHO group is not available for the reaction to occur.**

ILLUSTRATION 9.6

Complete the following reactions



Sol.

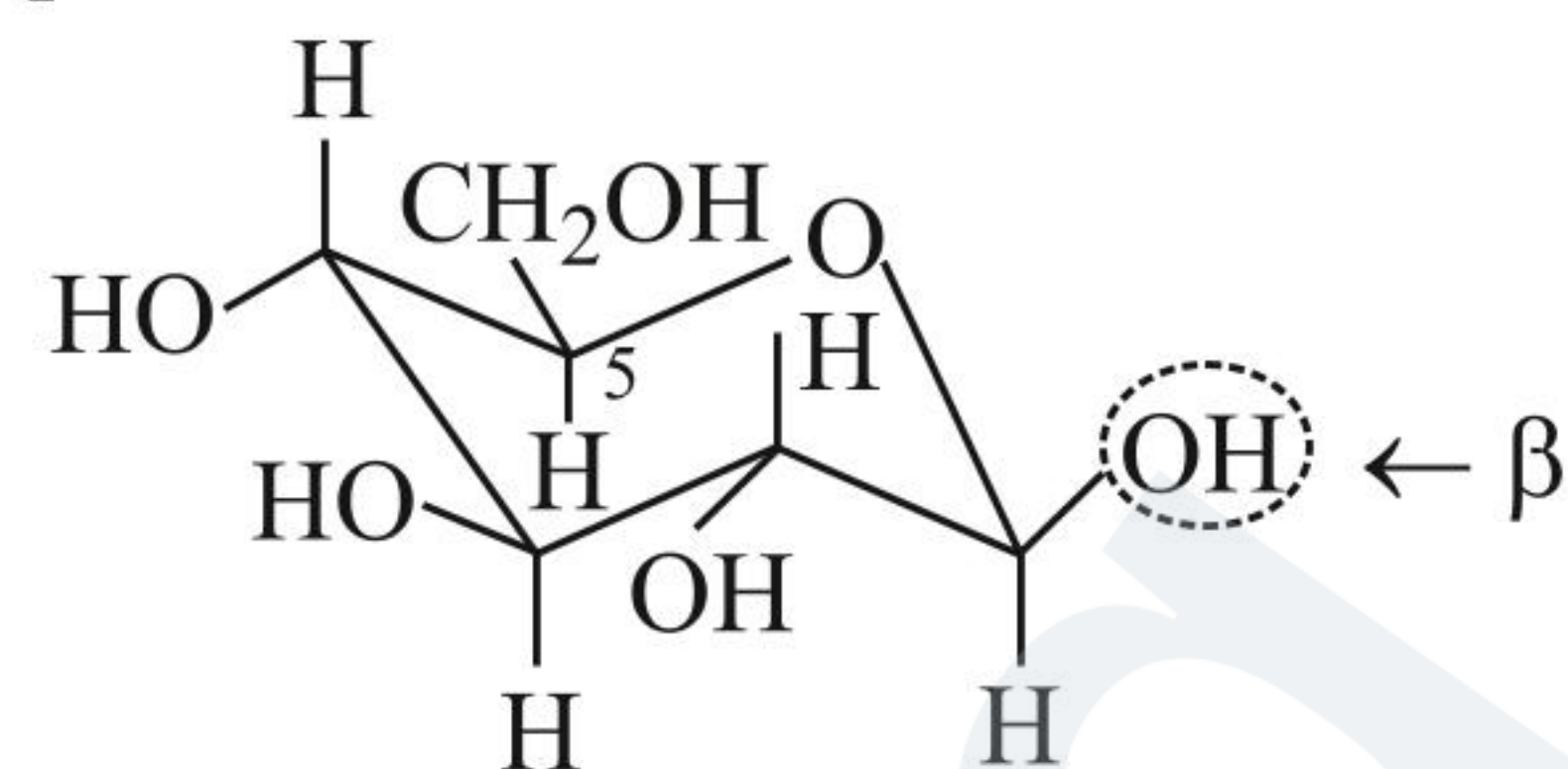
- Maltose is hydrolysed to give 2 mol of glucose.
- Since in maltose there is α -glycosidic linkage, maltase catalyses the hydrolysis of α -linkages only and gives 2 mol of glucose.
- No reaction; emulsin catalyses the hydrolysis of β -glycosidic linkages only.
- Gives positive Fehling's test (red precipitate of Cu_2O). Since maltose has free anomeric OH group and it is in equilibrium with the open-chain aldehyde form, it gives positive test with Tollens, Fehling's, and Benedict's reagents.
- With dil. NaOH, mutarotation occurs.
- An osazone is formed.
- The anomeric C-1 OH is oxidised to COOH group.

ILLUSTRATION 9.7

- Why is β -D-glucopyranose the most abundant of naturally occurring aldohexoses?
- Write the most stable chair conformer for α -D-fructopyranose. How does it differ from β -anomer?

Sol.

- All the ring substituents in the chair conformation are equatorial.



- See Section 9.3.9 (ii).

ILLUSTRATION 9.8

- What is the average molecular mass of starch?
- What is the approximate average number of glucose units in the sample of starch?
(Given: 20 gm L^{-1} of starch has an osmotic pressure = 10^{-2} atm at 25°C .)

Sol.

- $\pi = MRT$ (M = molarity of solution).

$$M = \frac{\pi}{RT} = \frac{10^{-2} \text{ atm}}{(0.082 \text{ L atm mol}^{-1} \text{ K}^{-1})(298 \text{ K})} = 4 \times 10^{-4} \text{ M.}$$

$$M = \frac{W_2 \times 1000}{\text{MW}_2 \times \text{vol. of solution in ml}}$$

$$\text{MW}_2 = \frac{20 \times 1000}{4 \times 10^{-4} \times 1000} = 5 \times 10^4 \text{ g mol}^{-1}$$

- Starch is a polymer of glucose; each glucose unit (MW of glucose = 180 g mol^{-1}) is joined to another glucose unit with loss of one H_2O unit (18 g mol^{-1}) giving a MW of $180 - 18 = 162 \text{ g mol}^{-1}$ per unit.

$\therefore$ Number of glucose units

$$= \frac{5 \times 10^4 \text{ gm mol}^{-1}}{162 \text{ gm mol}^{-1} \text{ unit}^{-1}}$$

$$= 309 \approx 310 \text{ glucose unit}$$

ILLUSTRATION 9.9

The specific rotation of α -glucose is $+112^\circ$ and β -glucose is $+19^\circ$ and the specific rotation of the constant equilibrium mixture is $+52.7^\circ$. Calculate the percentage composition of anomers (α and β) in the equilibrium mixture.

Sol. Let α - and β -glucose have a and $b\%$, respectively.

Equilibrium specific rotation

$$= \frac{(a \times \text{sp. rot. of } \alpha) + (b \times \text{sp. rot. of } \beta)}{100}$$

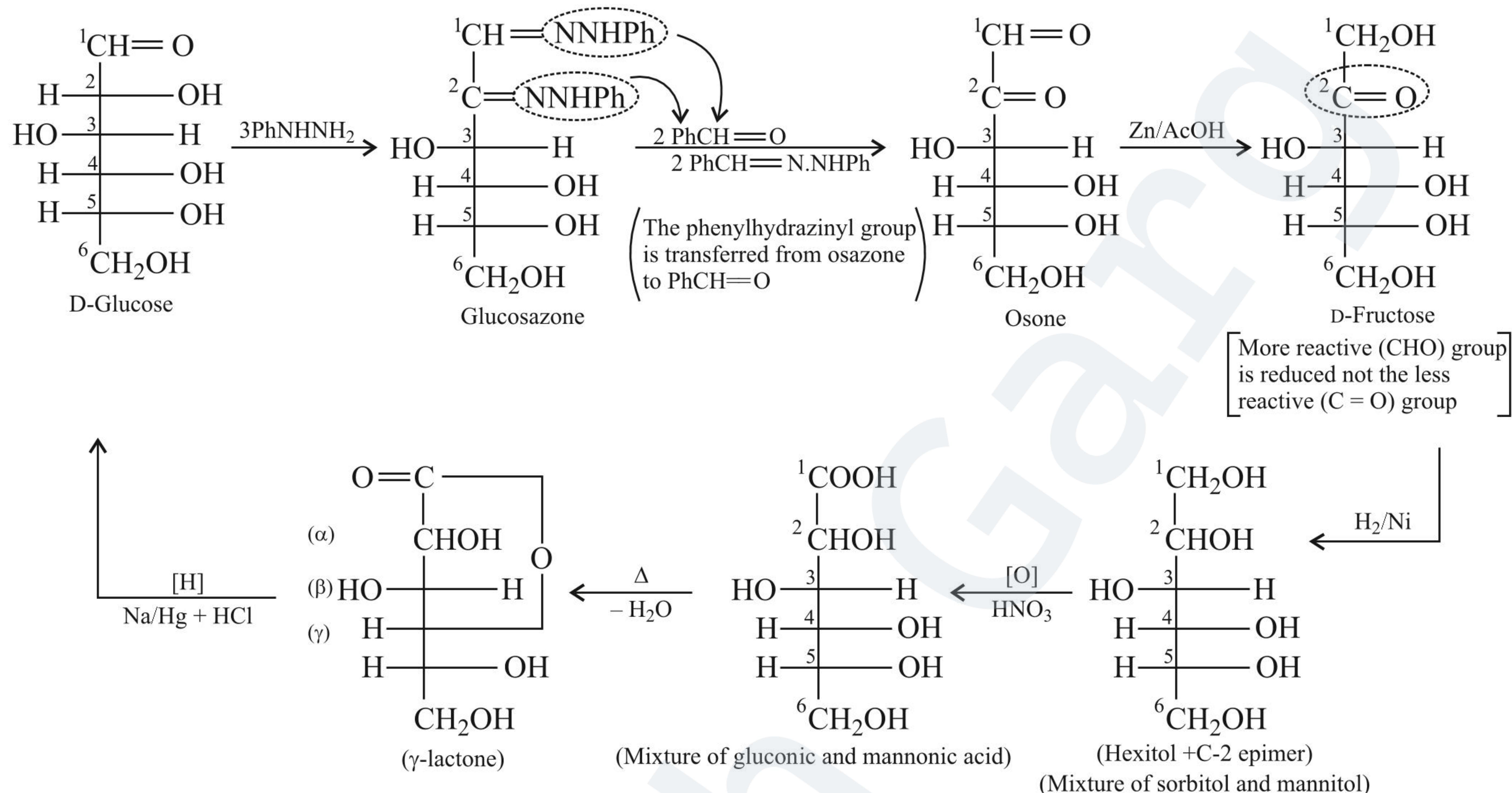
$$+52.7 = \frac{a \times 112 + b \times 19}{100}$$

$$= \frac{112a + (100 - a) \times 19}{100}$$

Solving for a and b : $a = 36.2\%$, $b = 63.8\%$

ILLUSTRATION 9.10

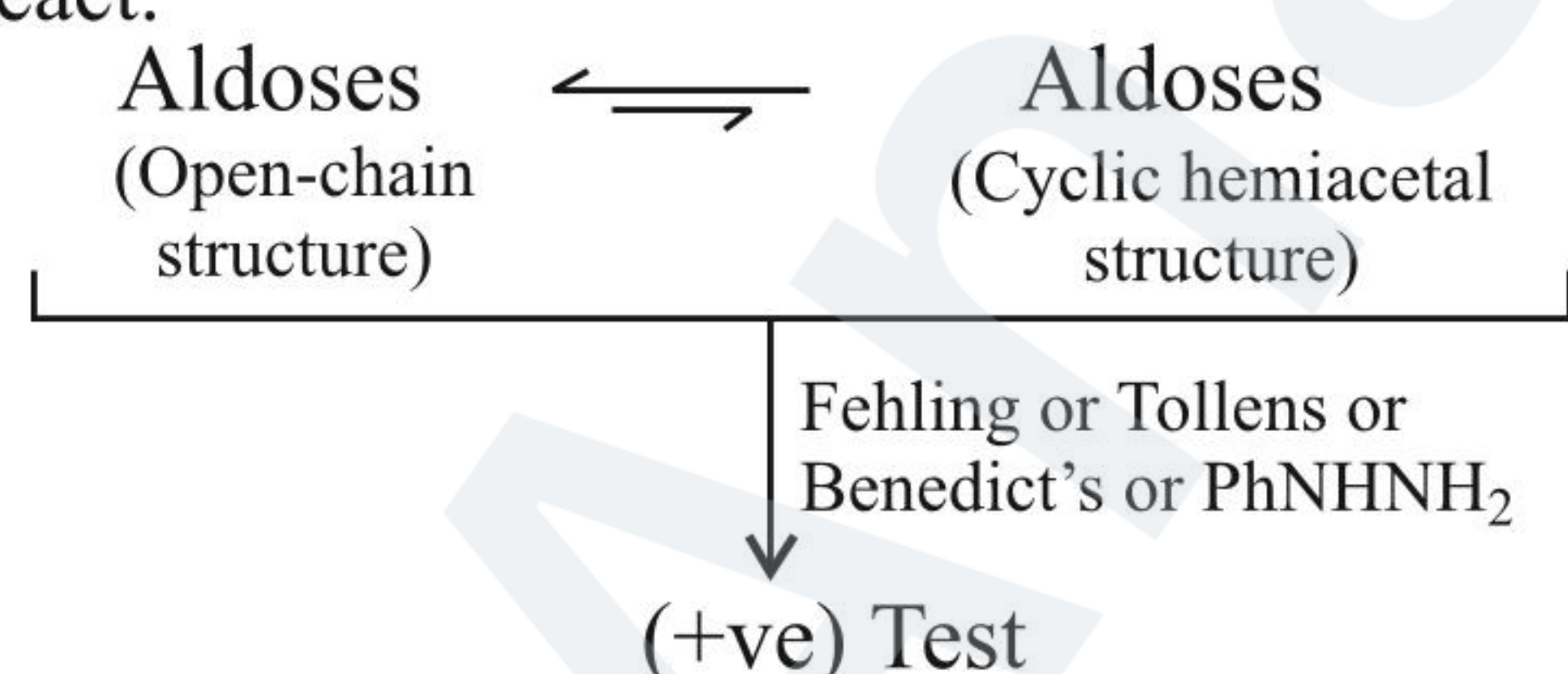
Give the steps for the conversion of D-glucose to D-fructose and *vice versa*.

Sol.**ILLUSTRATION 9.11**

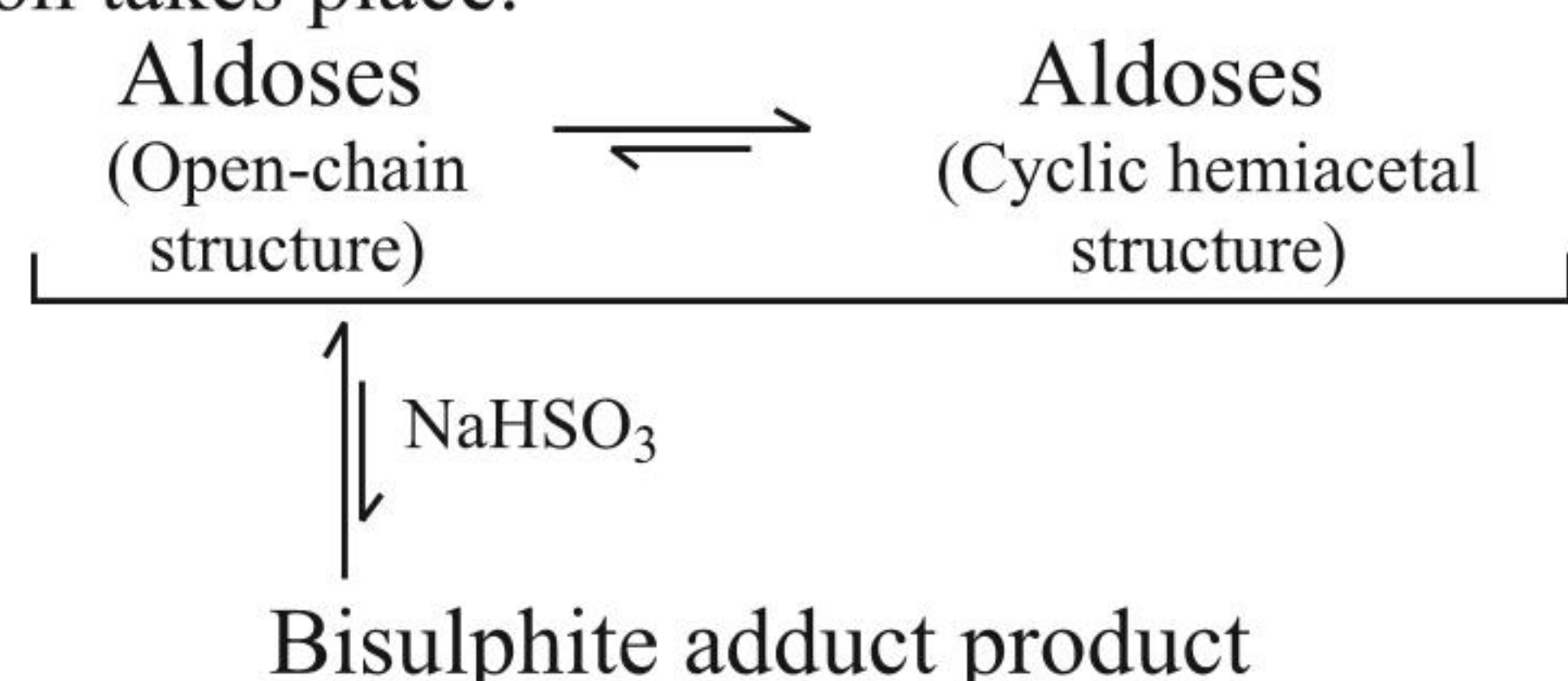
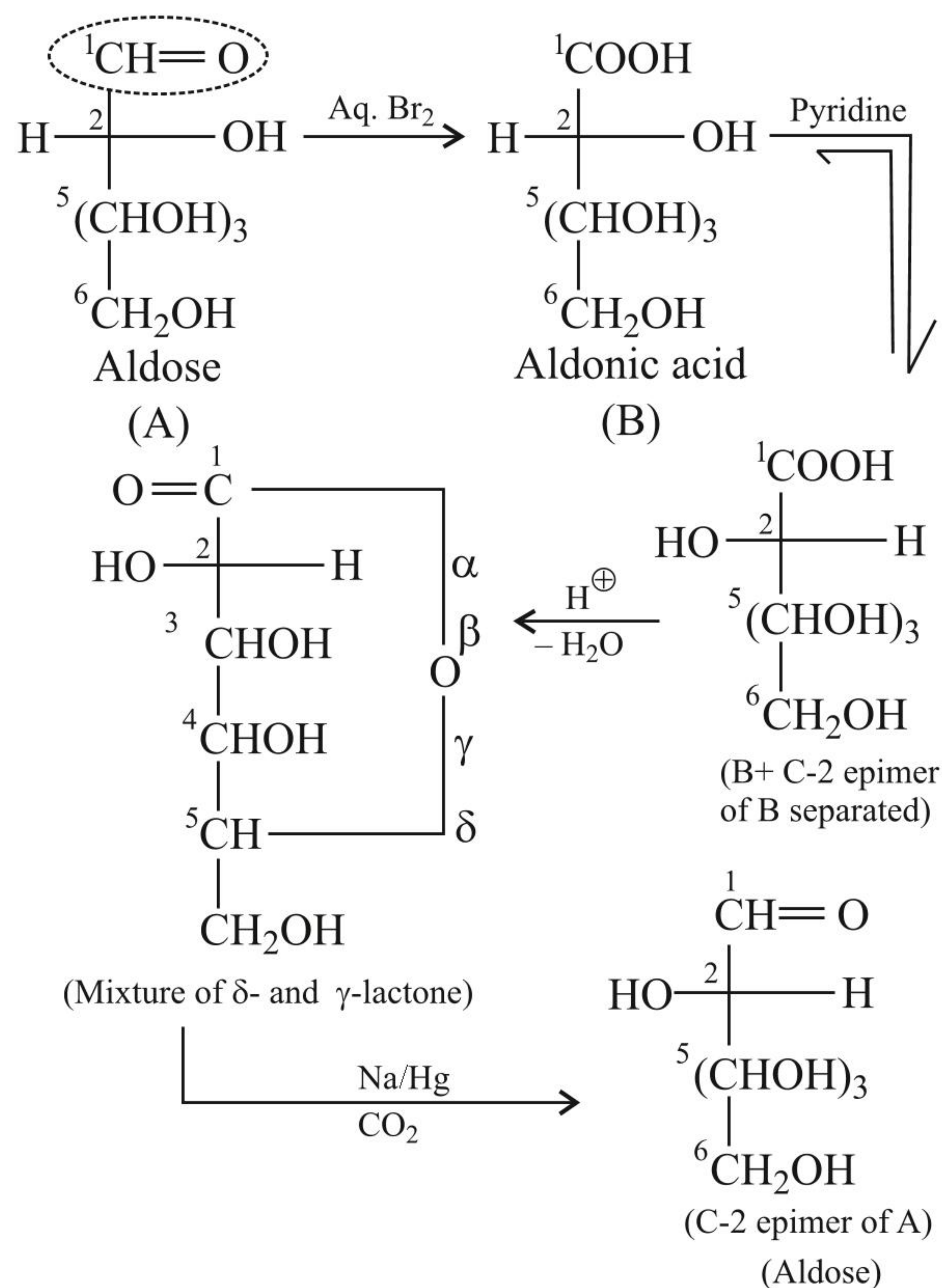
Explain why aldoses react with Benedict's solution and PhNHNH_2 , but not with NaHSO_3 .

Sol. Reaction of Benedict's solution and PhNHNH_2 is the reaction of CHO group, in which the open-chain aldehyde form is in equilibrium with the cyclic hemiacetal form.

Fehling's, Benedict's, and osazone reactions are irreversible. The equilibrium shifts to the open-chain aldehyde structure and they react.

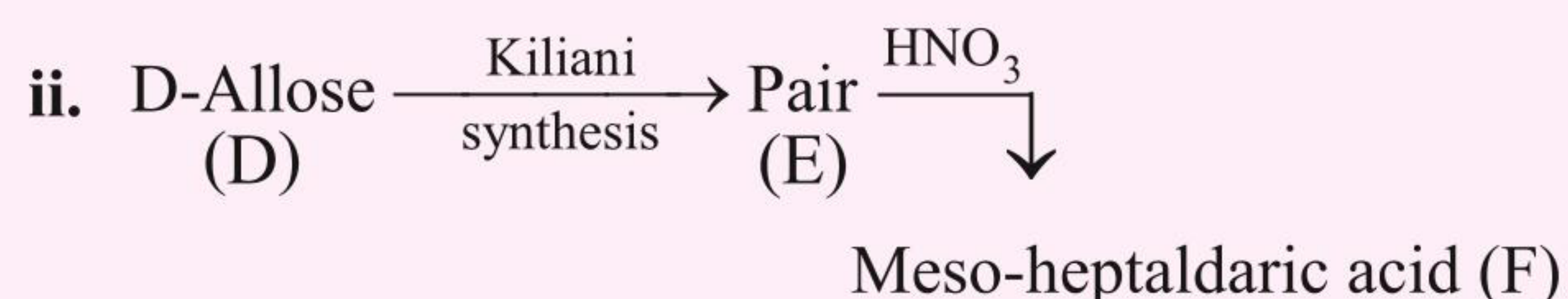
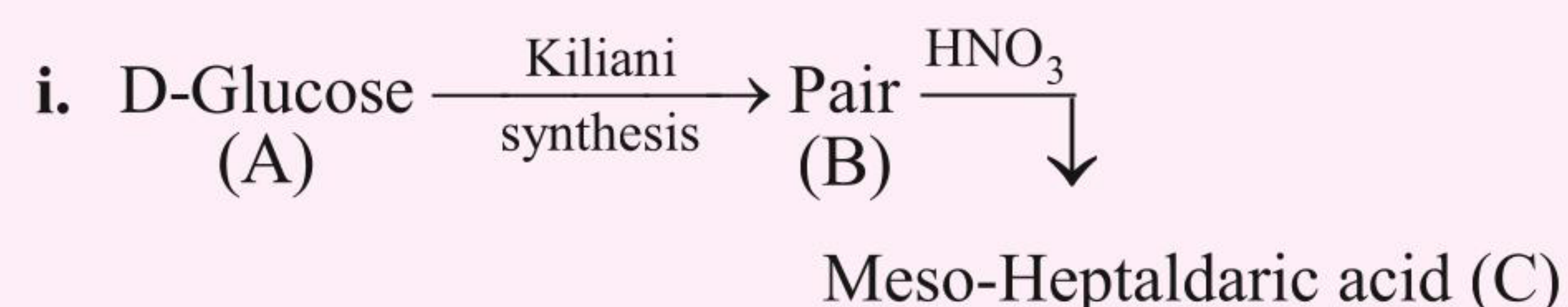


With NaHSO_3 , addition reaction is reversible and enough aldehyde remains in equilibrium with the bisulphite adduct to satisfy the equilibrium towards the hemiacetal form hence no reaction takes place.

**9.3.24 CONVERSION TO EPIMER (EPIMERISATION)**

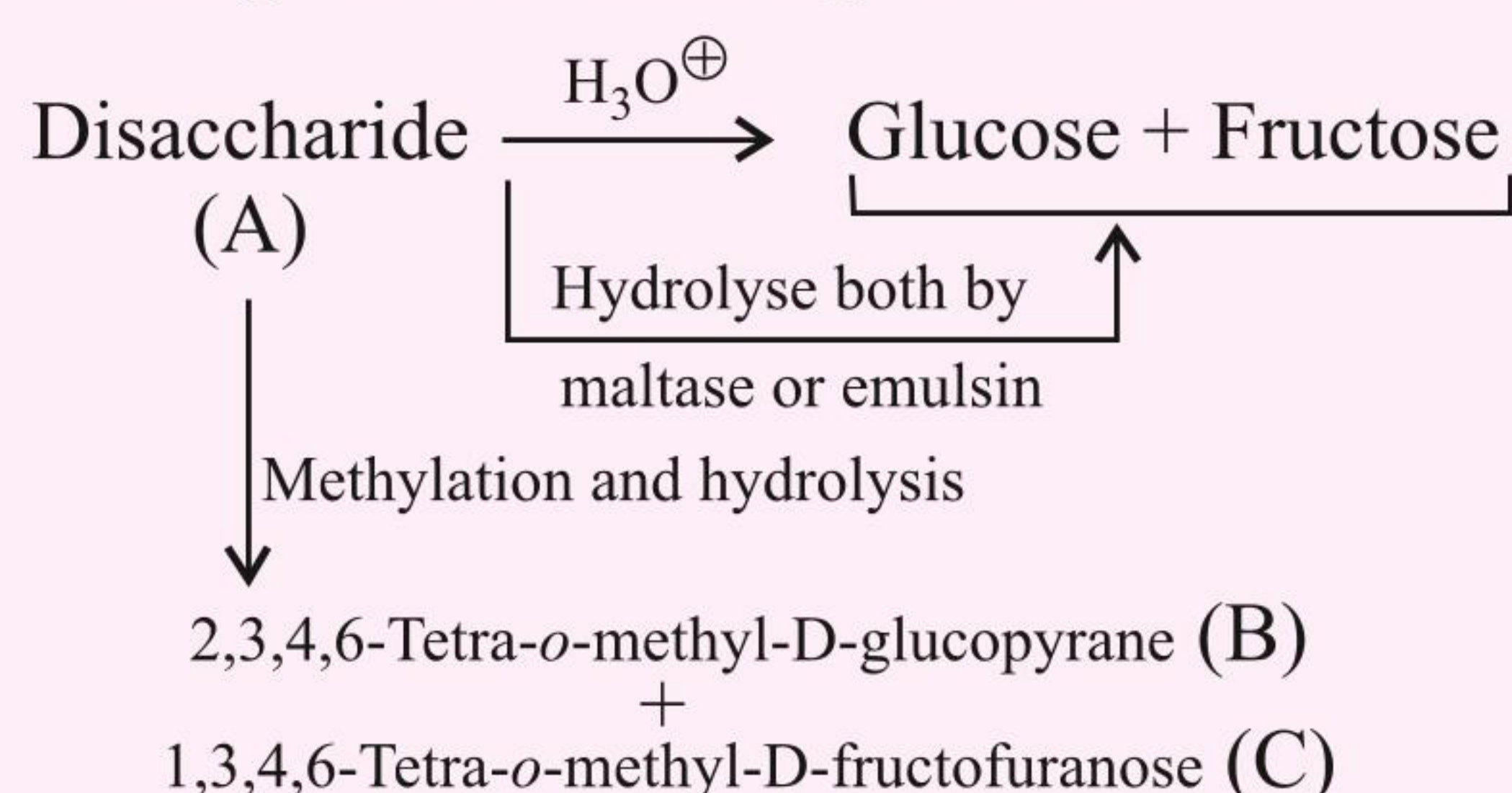
CONCEPT APPLICATION EXERCISE 9.1

1. Complete the following reactions:



Explain whether the acids (C) and (F) are same or different. Which pair out of (B) and (E) gives meso-acids (C) and (F)?

2. Give the structure and IUPAC name of disaccharide, which gives the reaction given below:



Given, (A) does not reduce Fehling's solution and does not mutarotate.

Nomenclature of Amino Acids

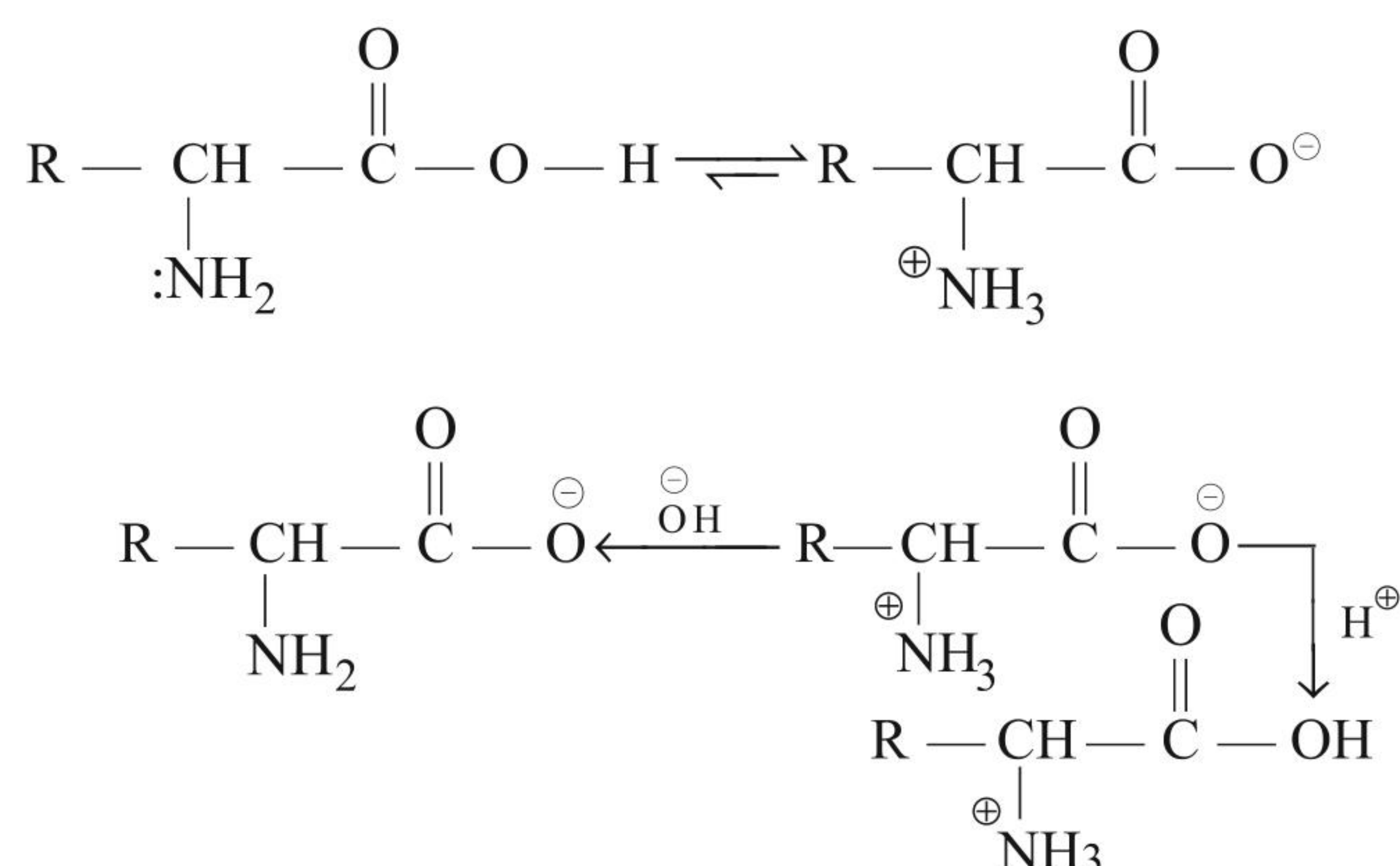
All amino acids possess minor names; it includes even those for which IUPAC names are not too complex, e.g., $\text{H}_2\text{NCH}_2\text{COOH}$ is commonly called **glycine** instead of α -amino acetic acid or 2-amino ethanoic acid. These minor names normally give an indication of the property of that compound or its source, e.g., glycine is thus named because it possesses sweet taste (in Greek, **tyros** means **cheese**). Amino acids are normally represented by a three-letter symbol, but sometimes one-letter symbol is also used. In Table 9.2, the structures of a few generally occurring amino acids alongside their three-letter and one-letter symbols are given.

Classification of Amino Acids

Amino acids are categorised as acidic, basic, or neutral based on the relative numbers of amino and carboxyl groups present in their molecules. If the number of amino and carboxyl groups is equal, they are neutral; when the number of amino groups is more than carboxyl groups, the amino acid is basic; and if the number of amino groups is less than carboxyl groups, it makes it acidic in character. Those amino acids that can be synthesised in the body are called nonessential amino acids, while the ones that cannot be synthesised in the body (but are obtained through diet) are termed as essential amino acids (see the starred entries in Table 9.2).

Physical Properties of α -Amino Acids

- a. Amino acids are normally colourless, water-soluble, and high melting and crystalline solids. Their behaviour is similar to salts rather than simple amines or carboxylic acids. This type of behaviour is because of the availability of both an acidic (carboxyl group) and a basic amino group in the same molecule. In aqueous solution, the carboxyl group might lose a proton while the amino group may accept a proton, forming a dipolar ion called **zwitter ion**. This ion is neutral but comprises both positive and negative charges.



Amino acids show amphoteric behaviour in zwitter ionic form because they react both with acids and bases. In acidic solution, the carboxylate function ($-\text{COO}^-$) takes a proton and is converted to carboxyl substituent ($-\text{COOH}$). However, in basic solution the ammonium substituent is converted to amino group ($-\text{NH}_2$) through losing a proton.

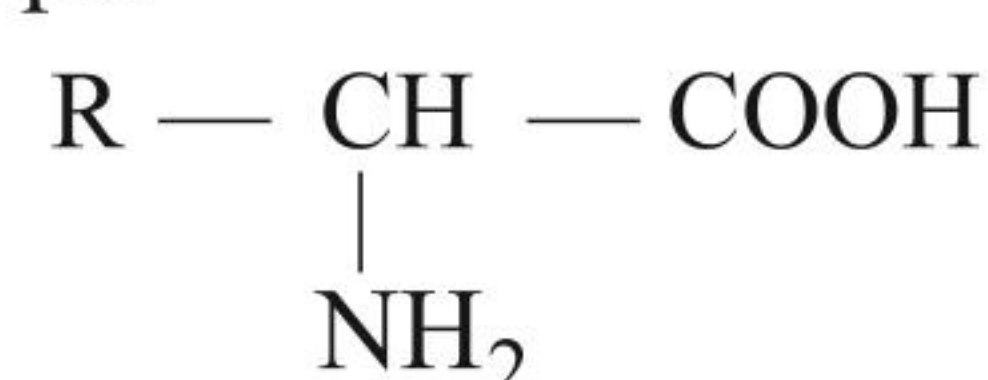
9.4 PROTEINS

Proteins are high molecular mass complex biopolymers of amino acids found in all living cells. They constitute 10–20% of the protoplasm of plant or animal cell. The name *protein* is adapted from the Greek word **proteios** meaning of **prime importance**. They perform multiple functions: as **enzymes** they catalyse biochemical reactions, as **hormones** they control metabolic processes, and as **antibodies** they defend the body against poisonous substances. All proteins possess the elements such as carbon, hydrogen, oxygen, nitrogen, and sulphur. Some of them also have phosphorus, iodine and small traces of metals such as copper, iron, zinc, and manganese. On partial hydrolysis, all proteins form peptides of different molecular masses that give amino acids on complete hydrolysis.



9.4.1 AMINO ACIDS

Amino acids have amino ($-\text{NH}_2$) and carboxyl ($-\text{COOH}$) functional groups. Based on the relative position of the two functional groups in the alkyl chain, the amino acids are categorised as α , β , γ , δ , and so on. On the hydrolysis of proteins, only α -amino acids are formed. Amino acids may also contain other functional groups.

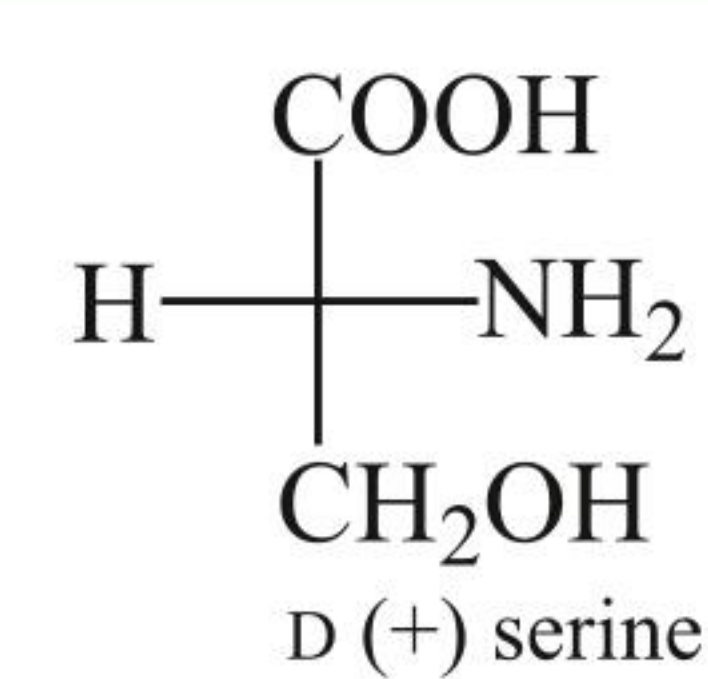
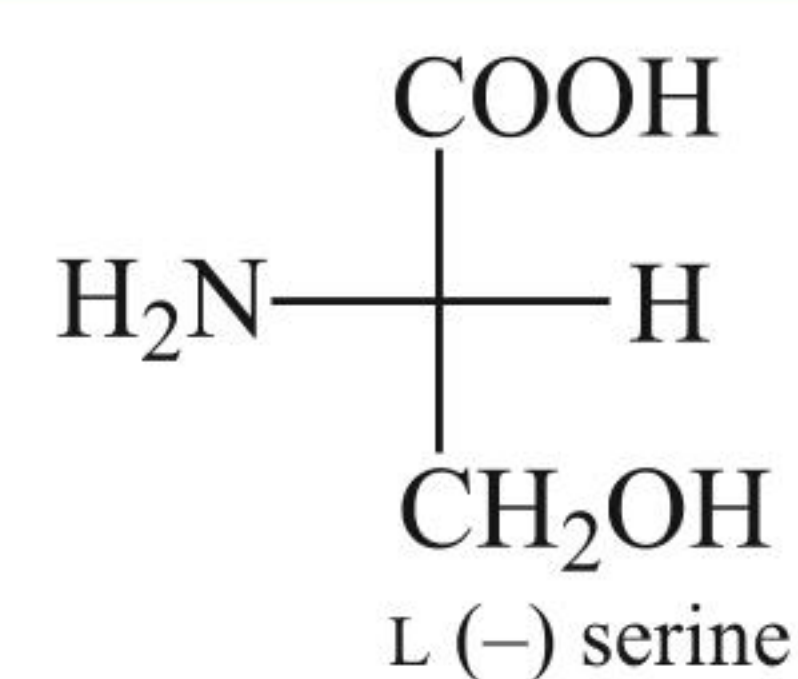


α -Amino acid (R = side chain)

In acidic solution, an amino acid is found as a positive ion and moves towards the cathode in an electric field. On the other hand, in alkaline solution it is available as a negative ion and migrates towards anode. At a specific hydrogen ion concentration (pH), the dipolar ion exists as a neutral ion and does not show migration towards any electrode. **This pH is termed as the isoelectric point of the amino acid.** The isoelectric point is dependent upon other functional groups in the amino acids. Neutral amino acids have their isoelectric points in the range of pH 5.5 to 6.3. **At isoelectric point, the amino acids are least soluble in water. This property is utilised in the separation of various amino acids formed by the hydrolysis of proteins.**

All naturally occurring α -amino acids, except glycine, are optically active because the α -carbon atom is asymmetric. They exist in both 'D' and 'L' forms. Their Fischer projection formulae are given with the carboxyl group (—COOH) at the top. In the 'D' form, the amino group (—NH_2) is given on the right, while in the 'L' form it is given on the left side. This arrangement is like the positioning of hydroxyl group (—OH) in glyceraldehydes, which is the reference compound for carbohydrates. 'D' and 'L' denote the configuration of amino acid molecule around the asymmetric carbon atom. Majority of the naturally happening amino acids possess L-configuration.

- b. For amino acid (+) serine is used as a configurational reference compound, since there is a configurational resemblance between L-glyceraldehyde and (–) serine. Therefore, (–) serine is given the configuration symbol L and (+) serine as D.



Chemical Properties of α -Amino Acids

Amino acids give salts with both acids as well as bases. Their chemical reactions are like carboxylic acids and primary amines.

a. Peptides

On hydrolysis, the proteins break down into smaller bits known as peptides that ultimately give α -amino acids.

The peptide bond: The reaction between two molecules of the same or different amino acids carries on through the combination of the carboxyl group of one molecule with the amino group of the other. As a result, a water molecule is eliminated and a peptide bond, —CO—NH— , is formed; For example, on the combination of carboxyl group of glycine with the amino group of alanine, glycylalanine is formed.

On the other hand, the amino group of glycine can react with carboxyl group of alanine, forming a different dipeptide, alanylglycine (Ala-Gly).

In both dipeptides (glycylalanine and alanyl-glycine) free functional groups are available at both ends. These groups further react with the appropriate groups of the other amino acids resulting in the formation of tri-, tetra-, penta-peptides, and so on.

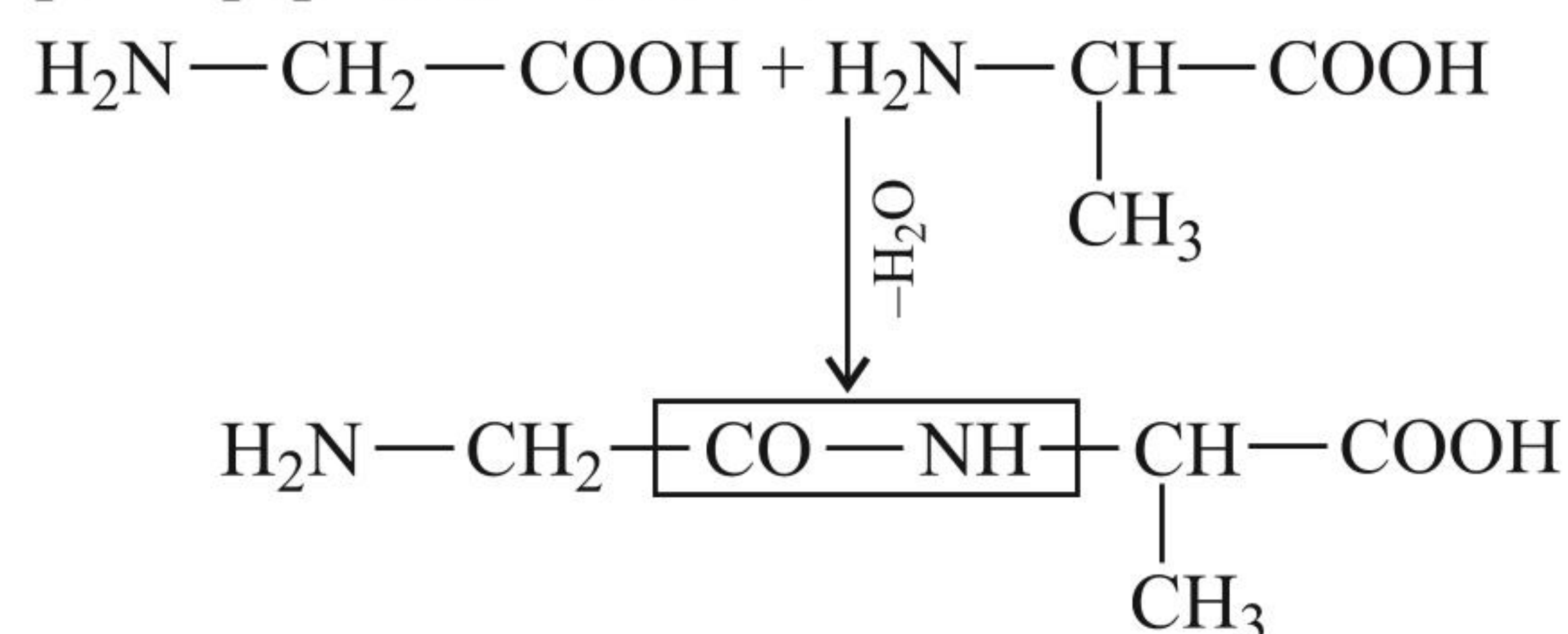
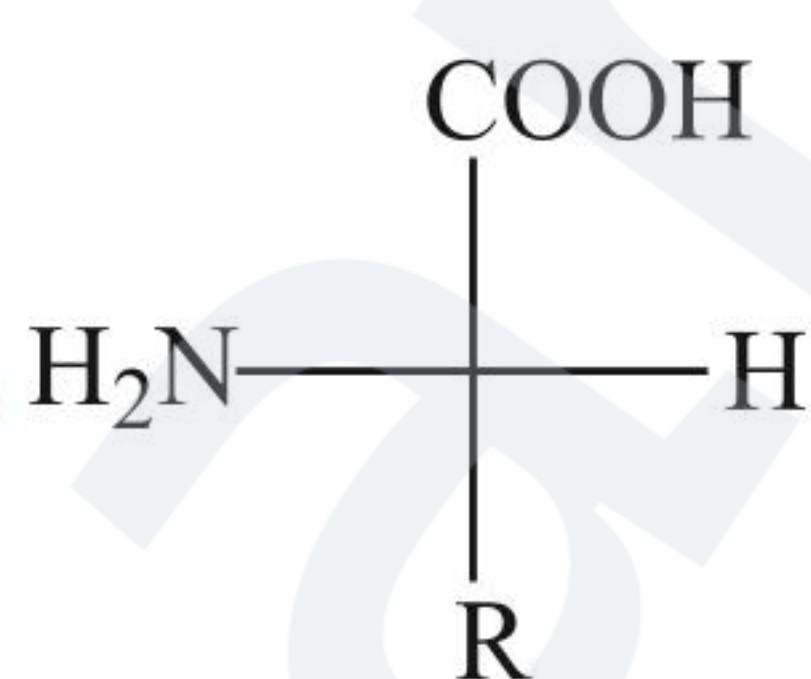
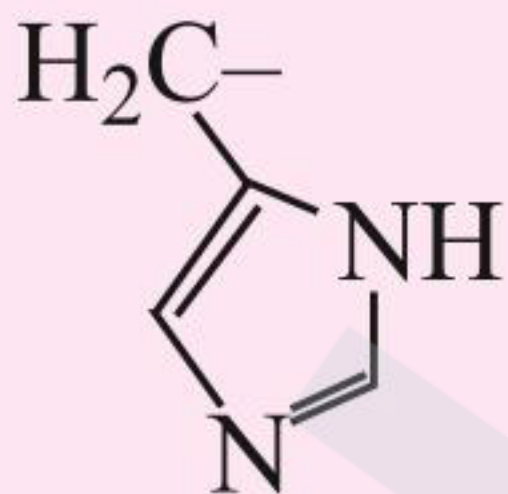
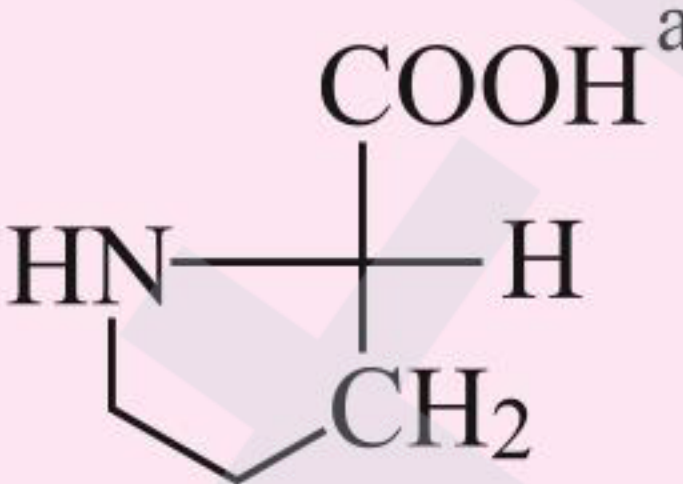


Table 9.2 Natural amino acids,

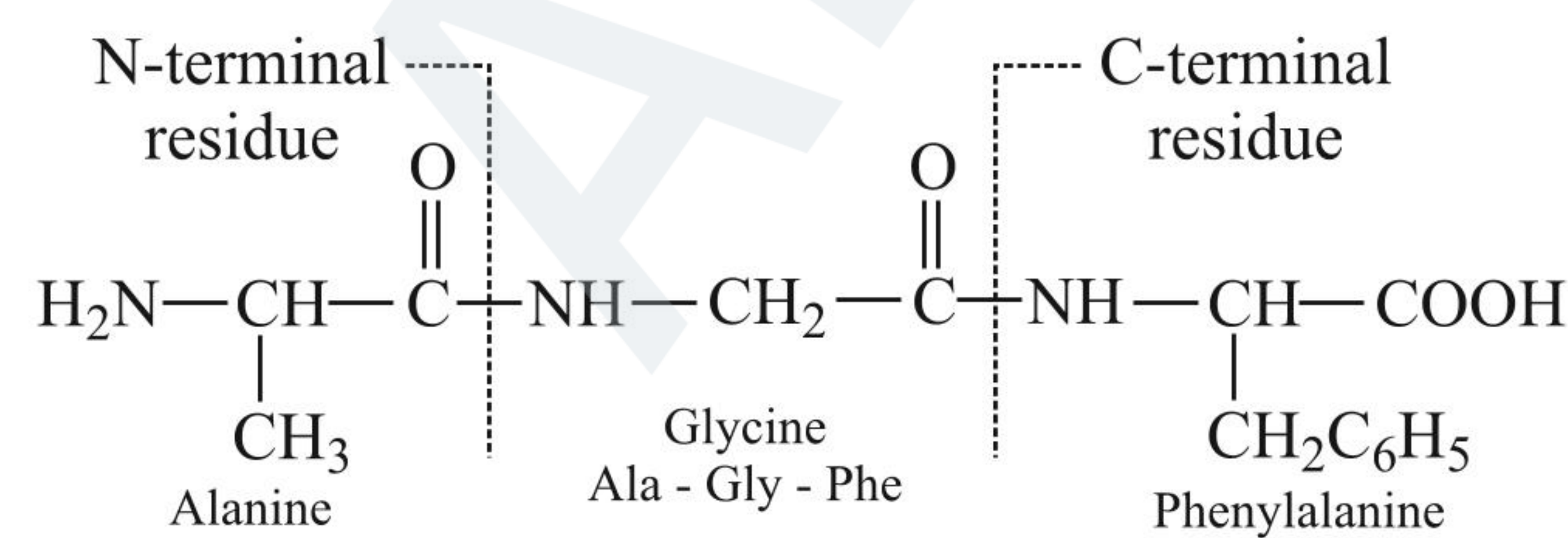


Amino acids	Characteristic feature of side chain, R	Three-letter symbol	One-letter code
1. Glycine	H	Gly	G
2. Alanine	—CH_3	Ala	A
3. Valine*	$(\text{H}_3\text{C})_2\text{CH} \text{—}$	Val	V
4. Leucine*	$(\text{H}_3\text{C})_2\text{CH} \text{—CH}_2 \text{—}$	Leu	L
5. Isoleucine*	$\text{H}_3\text{C} \text{—CH}_2 \text{—} \underset{\text{CH}_3}{\text{CH}}$	Ile	I
6. Arginine*	$\text{HN} = \underset{\text{NH}_2}{\text{C}} \text{—NH} \text{—} (\text{CH}_2)_3 \text{—}$	Arg	R
7. Lysine*	$\text{H}_2\text{N} \text{—} (\text{CH}_2)_4 \text{—}$	Lys	K

8. Glutamic acid	HOOC — CH ₂ — CH ₂ —	Glu	E
9. Aspartic acid	HOOC—CH ₂ —	Asp	D
10. Glutamine	$\begin{array}{c} \text{O} \\ \parallel \\ \text{H}_2\text{N} - \text{C} - \text{CH}_2 - \text{CH}_2 - \end{array}$	Gln	Q
11. Asparagine	$\begin{array}{c} \text{O} \\ \parallel \\ \text{H}_2\text{N} - \text{C} - \text{CH}_2 - \end{array}$	Asn	N
12. Threonine*	H ₃ C — CHOH —	Thr	T
13. Serine	HO — CH ₂ —	Ser	S
14. Cysteine	HS — CH ₂ —	Cys	C
15. Methionine*	H ₃ C — S — CH ₂ — CH ₂ —	Met	M
16. Phenylalanine*	C ₆ H ₅ — CH ₂ —	Phe	F
17. Tryptophan*	(p) HO — C ₆ H ₄ — CH ₂ —	Tyr	Y
18. Tyrosine		Trp	W
19. Histidine*		His	H
20. Proline		Pro	P
* Essential amino acid			

b. Polypeptides

As a matter of principle, the structure of polypeptides is presented in such a manner that the amino acid with the free amino (—NH₂) group termed as N-terminal residue is given on the left side of the polypeptide chain, while the amino acid with the free carboxyl group (C-termial residue) is given on the right side of the chain.



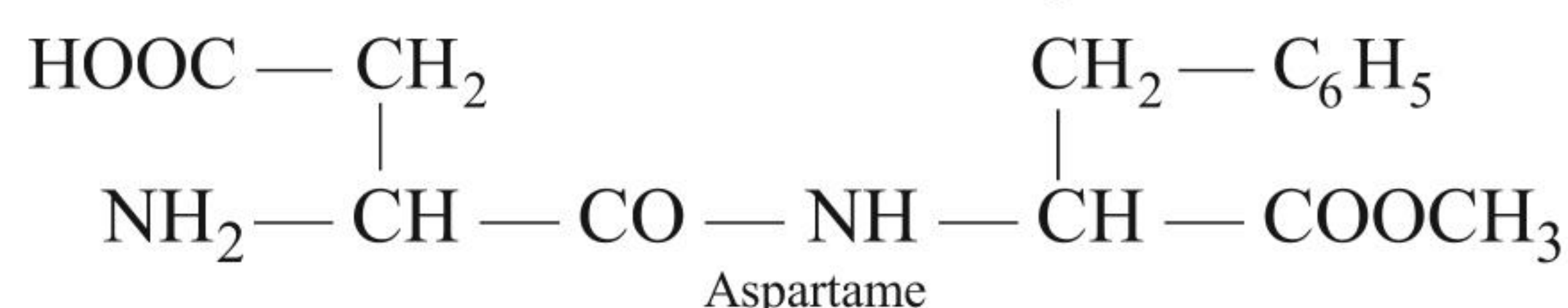
A polypeptide’s name is written beginning from the N-terminal residue. The suffix **-ine** coming in the name of the amino acid is substituted by **-yl** (e.g., alanine to alanyl, glycine to glycy, etc.) for all amino acids except the C-terminal acid. However, this nomenclature is not

used usually. As an alternative, we use the three-letter or one-letter abbreviation for the amino acid (Table 9.2), e.g., the tripeptide given above is known as Ala-Gly-Phe or A-G-F.

Comparatively, shorter peptides are termed as **oligopeptides**, whereas longer polymers are known as **polypeptides**. The protein is a polypeptide having more than hundred amino acid residues and a molecular mass more than 10,000. Nonetheless, the difference between a polypeptide and a protein is not very well defined. Polypeptides with lesser amino acids are usually known as proteins if they generally possess the specific conformation of a protein.

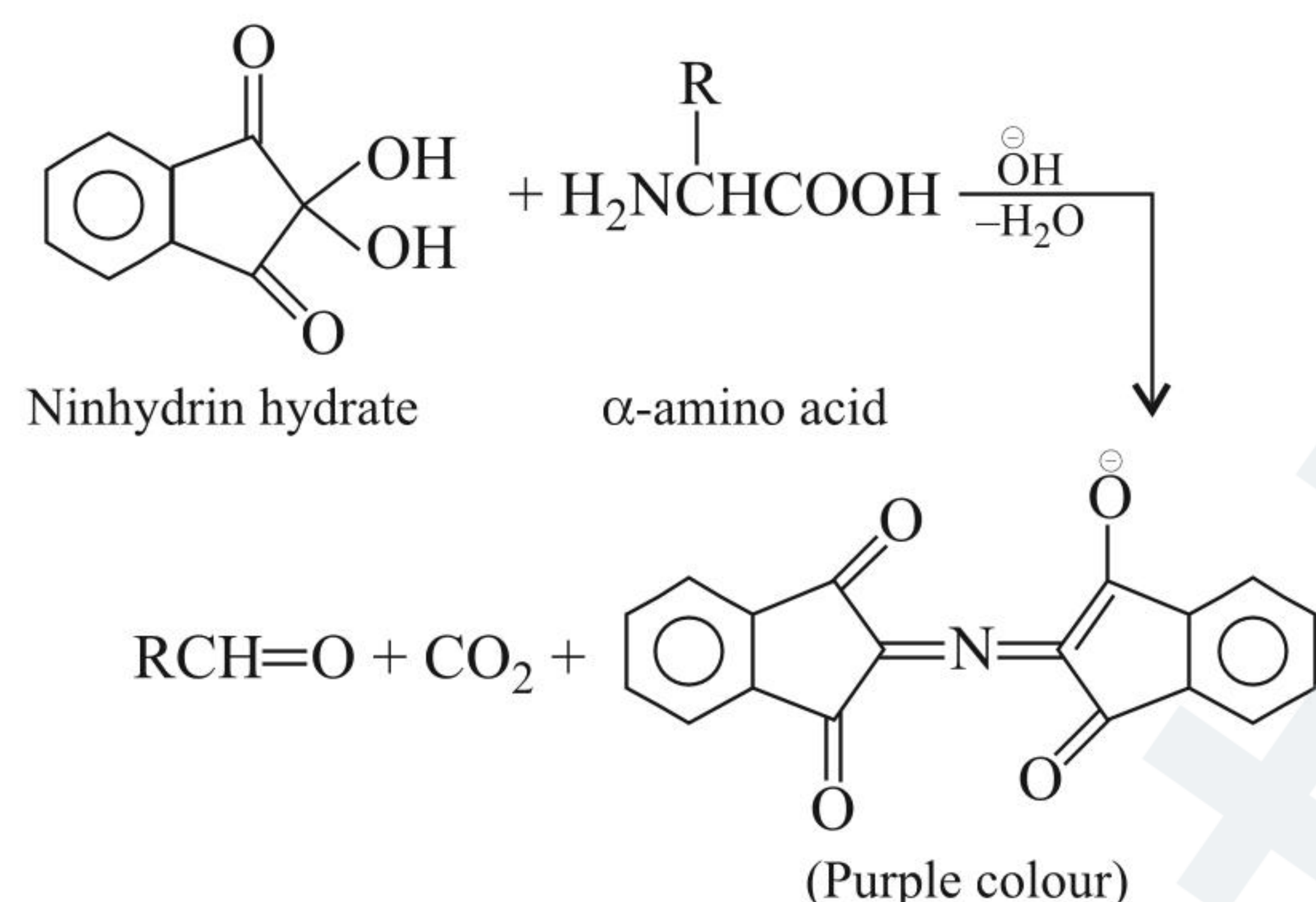
The availability of terminal ammonium and carboxylate ions as well as the ionised side chains of amino acid residues makes the polypeptides amphoteric in nature. So, they titrate as acids or bases and possess an isoelectric point at which they are recurrently least soluble apart from having the greatest propensity to aggregate.

The functions of proteins are very vital and diverse in biosystems. However, the smaller peptides also play an important role, although their total substance in tissues is relatively very small in comparison to proteins. Some of them are very strong. Majority of the toxins or the poisonous substances in animal venoms and in plant sources are polypeptides. A minuscule amount of some oligopeptides along with as little as three modified amino acid residues is effective as hormones. Aspartylphenylalanine methyl ester (aspartame), a derivative of dipeptide, is 160 times as sweet as sucrose and is used as a sugar substitute.



1. Ninhydrin Test: (For amino acid).

Ninhydrin hydrate on reaction with α -amino acids gives purple colour. The purple colour is detected by a spectrometer which measures its intensity and plots it as a function of time.



2. Biuret Test: (Test for proteins).

It is a biochemical test to detect proteins in solution named after the substance biuret ($\text{H}_2\text{NCONHCONH}_2$) which is formed when urea (H_2NCONH_2) is heated. NaOH is mixed with test solution and drops of 1% CuSO_4 is added slowly. A violet ring caused by the reaction of peptide bonds in the proteins or peptides. Such a result will not occur in presence of free amino acids.

ILLUSTRATION 9.12

A tripeptide on complete hydrolysis gives glycine, alanine, and phenylalanine. Using three-letter symbols write down the possible sequences of the tripeptide.

Sol. The possible combinations can be:

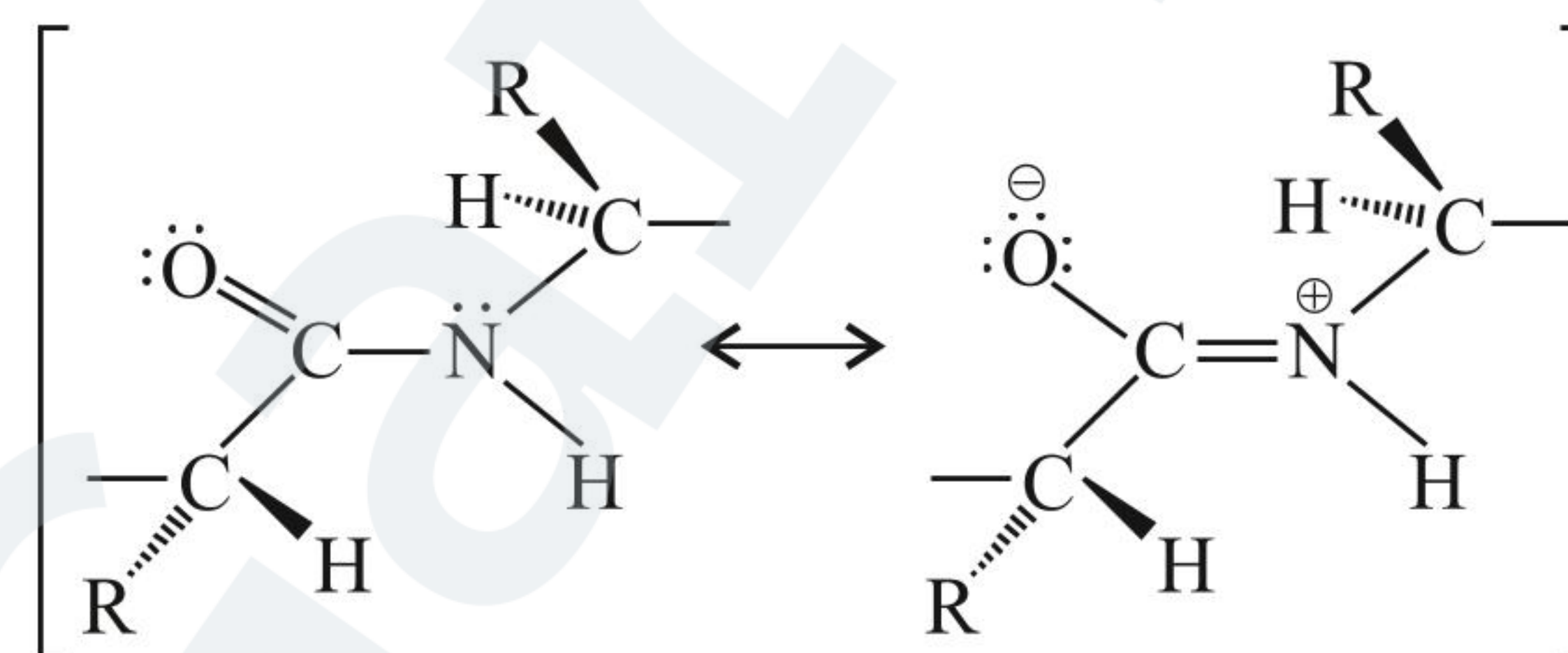
- | | |
|------------------|-----------------|
| i. Gly-Ala-Phe | ii. Gly-Phe-Ala |
| iii. Ala-Gly-Phe | iv. Ala-Phe-Gly |
| v. Phe-Gly-Ala | vi. Phe-Ala-Gly |

9.4.2 Structure of Proteins

Proteins are considered as the biopolymers having a large number of amino acids linked to each other through peptide linkages

containing three-dimensional (3D) structures. Protein structure and shape can be studied and evaluated at four separate levels, i.e., primary, secondary, tertiary, and quaternary structures. Each of these levels is more complex than the previous one.

- Primary structure of proteins:** The manner and sequence in which different amino acids are joined to form polypeptides in a protein molecule is called 1° structures of protein.
- Secondary structure:** The conformation in which the polypeptide chains assume a shape as a result of H-bonding is called the 2° structure of protein.



Resonance structure of amide linkage

Due to the fractional double bond nature of the C—N bond in peptide linkage, the amide part, i.e., —CO—NH— is planar and inflexible, i.e., free rotation about this bond is not possible. As shown in Fig. 9.3, the free rotation of a peptide chain can only happen around the bonds linking the almost planar amide groups to the α -carbons. **The angles Φ and Ψ in the figure are called Ramachandran angles, named after the Indian biophysicist, G.N.A. Ramchandran.** It is to be noted that —NH and C=O groups of the peptide bond are *trans* to each other.

i. α -Helix structure:

The hydrogen bonds between —C=O and —N—H groups of peptide bonds provide stability to the structure. So, a structure containing maximum hydrogen bonds is favoured. α -Helix is one of the most common means by which a polypeptide chain forms all probable hydrogen bonds by twisting into a right-handed screw (helix) with the —NH group of each amino acid residue hydrogen bonded to the C=O of an adjacent turn of the helix as shown in Fig. 9.4 (b). **The α -helix is also called as 3.6₁₃ helix, because each turn of the helix possesses about 3.6 amino acids and also the hydrogen bonding forms a 13-member ring.**

It is worth mentioning that in proteins, the helix always has a right-handed arrangement. If one holds his/her hand in a manner so that the thumb points towards the direction of travel along the axis of the helix, the curl of fingers identifies the direction of rotation of the helix [Fig. 9.4 (a)]. All amino acids in a polypeptide chain possess L-configuration and hence, it results in a stable helix if it is right handed. The ball and stick model of the α -helix is depicted in Fig. 9.4 (c).

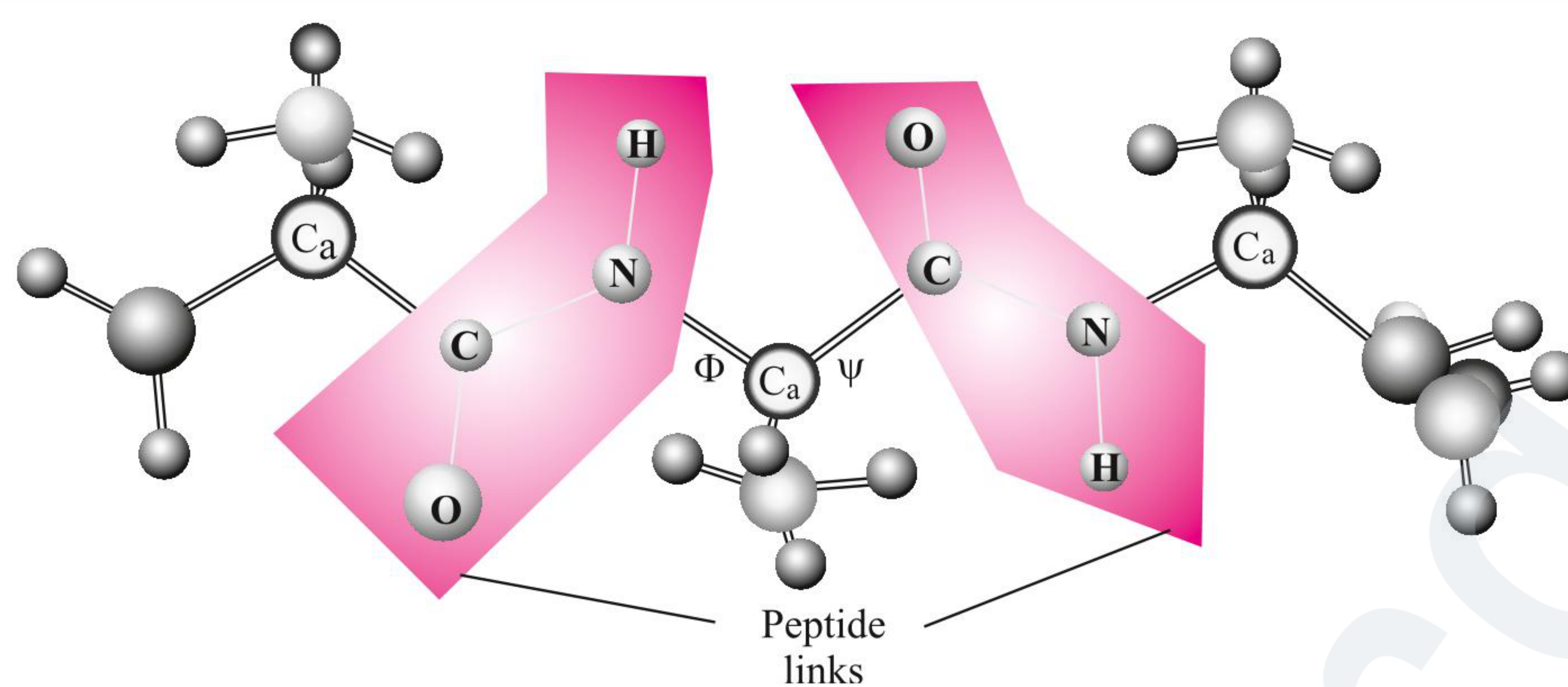


Fig. 9.3 Model of a tripeptide depicting peptide bonds and Ramchandra angles of rotation (Φ and Ψ) around α -carbon

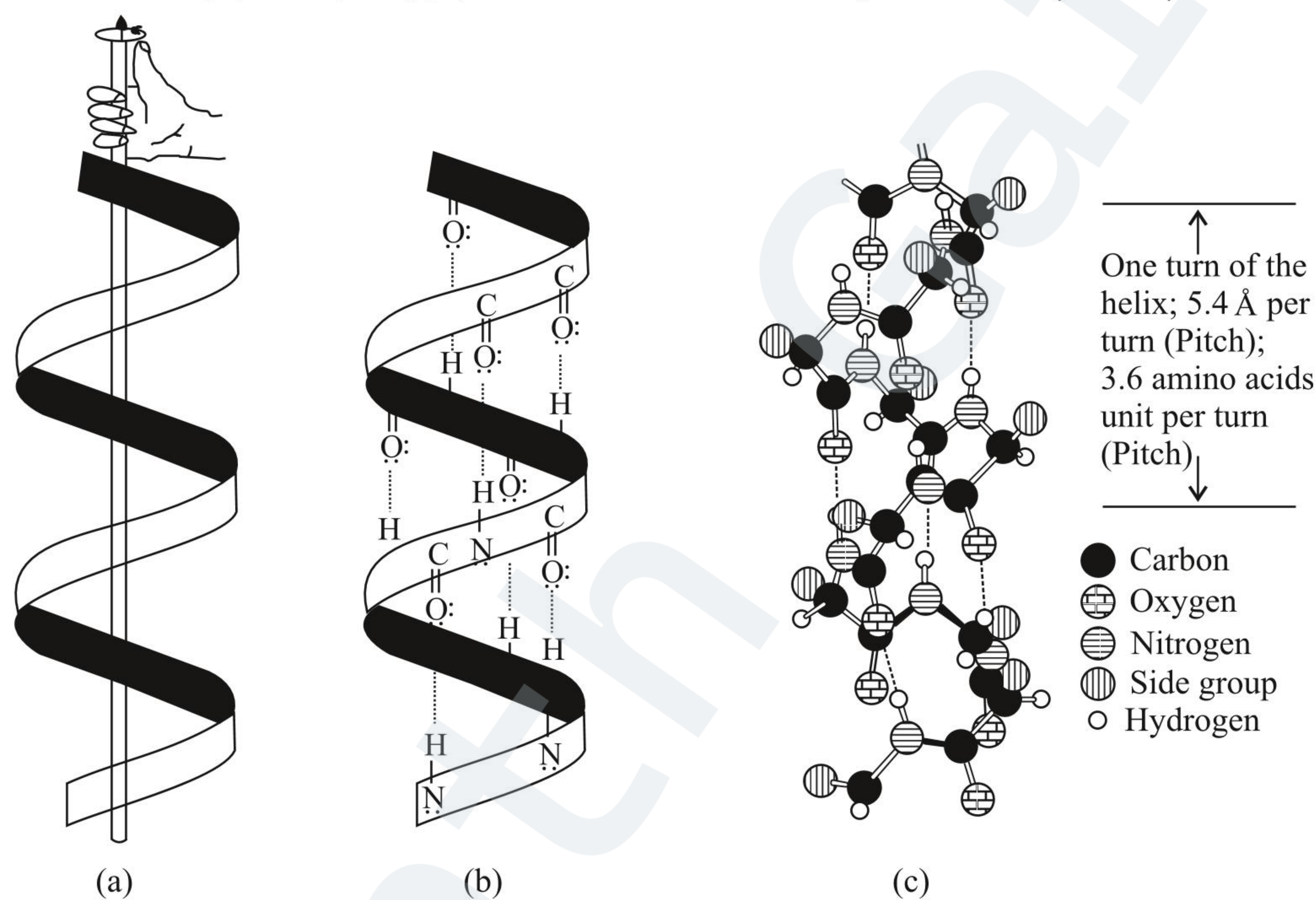


Fig. 9.4 α -Helix structure of proteins

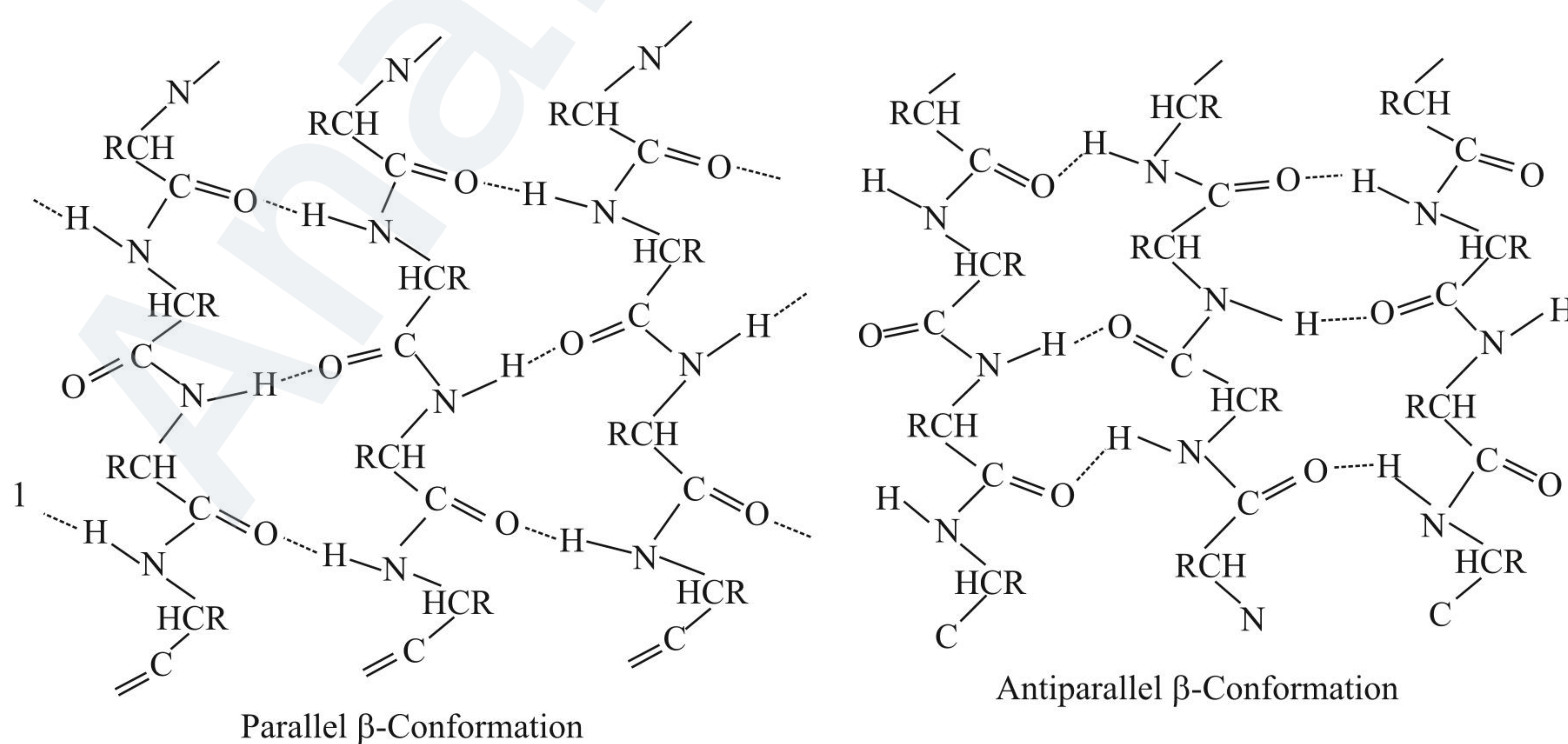


Fig. 9.5 β -Conformation of proteins

ii. **β -Pleated sheet structure:** This structure was proposed by Linus Pauling and coworkers in 1951. In this type of conformation, all peptide chains are expanded to almost maximum extension and afterwards laid side by side, being held together by the intermolecular hydrogen bonds. The structure appears like the pleated folds of drapery and hence called β -pleated sheet. The polypeptide chains may run parallel (in the same direction) or may be antiparallel (in opposite directions) (Fig. 9.6).

N-termini are aligned head to head (on the same side in parallel); β -conformation are aligned head to tail. In antiparallel conformation, N-terminus of one chain and C-terminus of another chain fall on the same side. In keratin (the protein present in hair), the β -sheet is parallel and it is antiparallel in silk fibroin.

c. **Tertiary structure of proteins:** The 3° structure of a protein pertains to its entire 3D structure, i.e., the way in which the whole protein molecule folds up in the 3D space to form a particular shape.

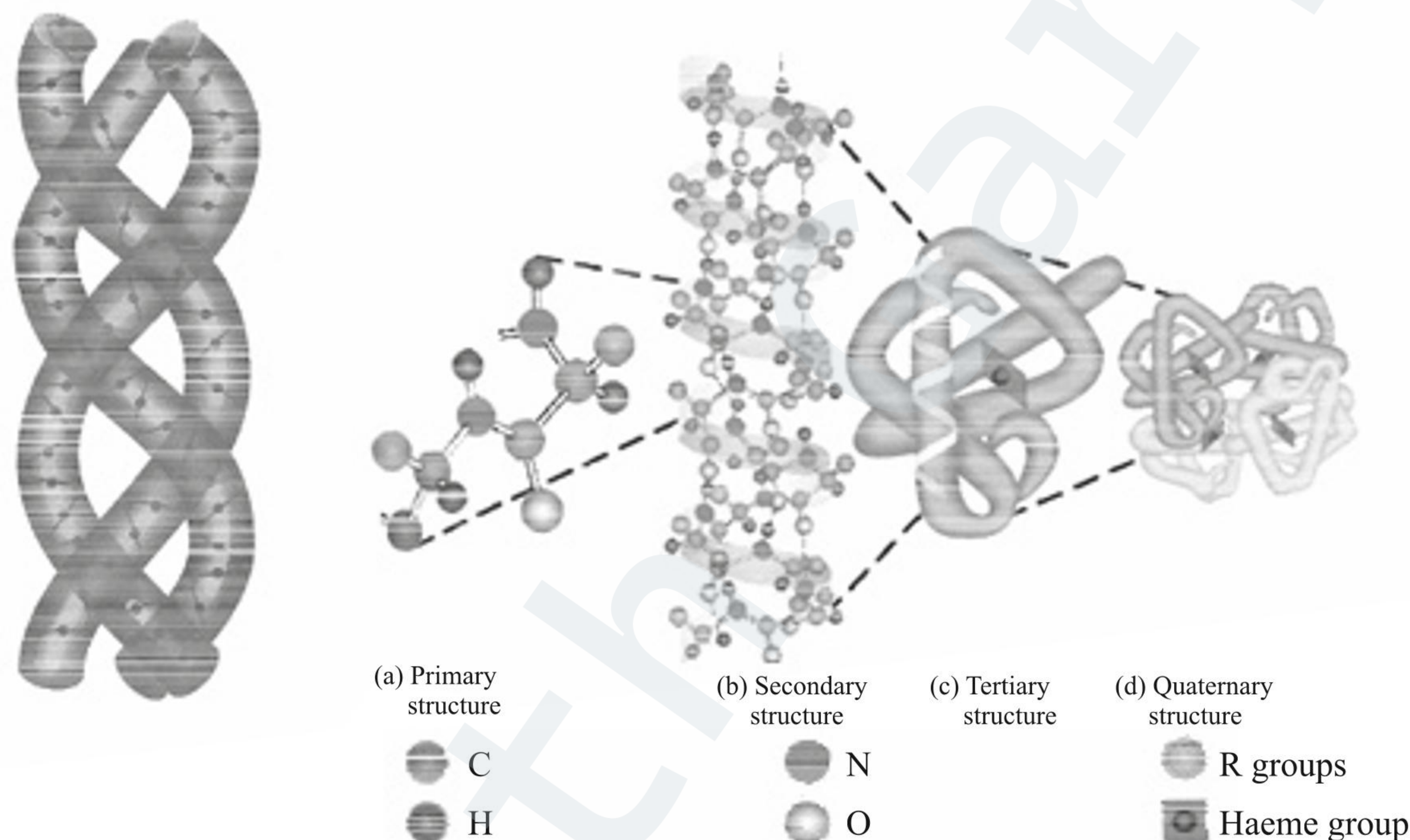


Fig. 9.6 Primary, secondary, tertiary and quaternary structure of haemoglobin

The primary, secondary, and higher (tertiary and quaternary) levels of haemoglobin structure are given in Fig. 9.6.

d. **Denaturation of Proteins:** The protein found in a biological system with a specific configuration and biological activity is known as a native protein. The native protein is considered to be **denatured** if on being subjected to physical or chemical treatment (that might dislocate its higher structures (conformations) without upsetting its primary structure) it loses its biological activity. The denaturation can be of two types: reversible and irreversible. An example of **irreversible protein denaturation** is the clotting of egg white on the boiling of egg protein. Nevertheless, in a few cases it is seen that if the upsetting agent is detached the protein regains its original physical and chemical properties as well as the biological activity. The opposite of denaturation is called **renaturation**.

e. **Classification of proteins**

On the basis of molecular structure, proteins are classified as:

i. Fibrous proteins

ii. Globular proteins

i. **Fibrous proteins:** They are linear or thread-like molecules, lying side by side to form fibres. The polypeptide chains are held by H-bonding and some by disulphide (—S—S—) bonds, and hence have high intermolecular forces of attraction. Thus, they are insoluble in H_2O and are stable to moderate changes of pH and temperature.

They are chief structural materials of animal tissues, e.g., keratin in skin, hair, wool, nails; collagen in tendons; fibroin in silk; and myosin in muscles.

ii. **Globular proteins:** The folding of polypeptide chains gives a spheroidal shape in which hydrophobic (non-polar) parts are inward and hydrophilic (polar) parts

are outwards, thus water molecules interact strongly with the polar groups and hence they are water soluble. They are very sensitive to small changes of pH and temperature.

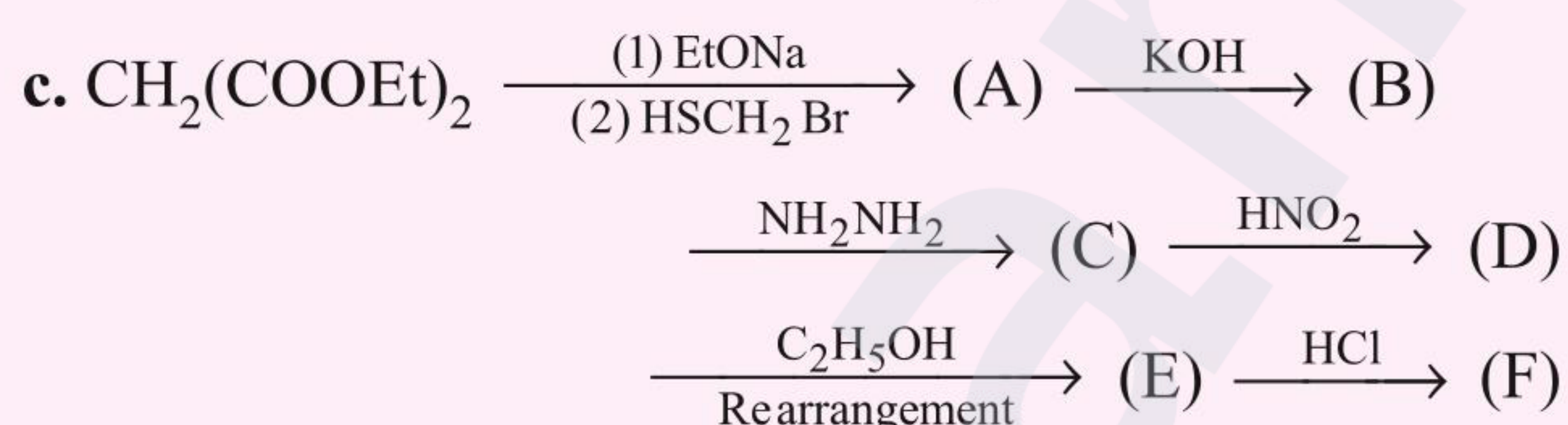
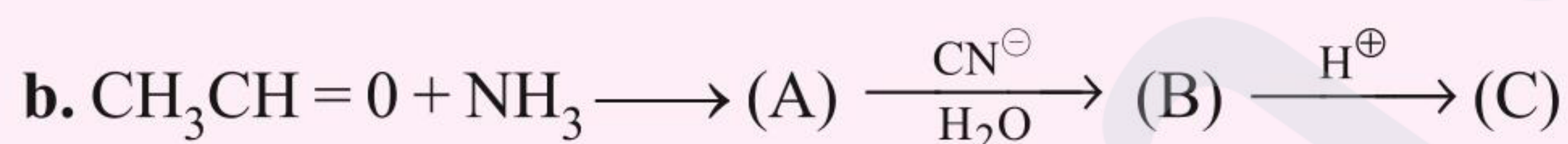
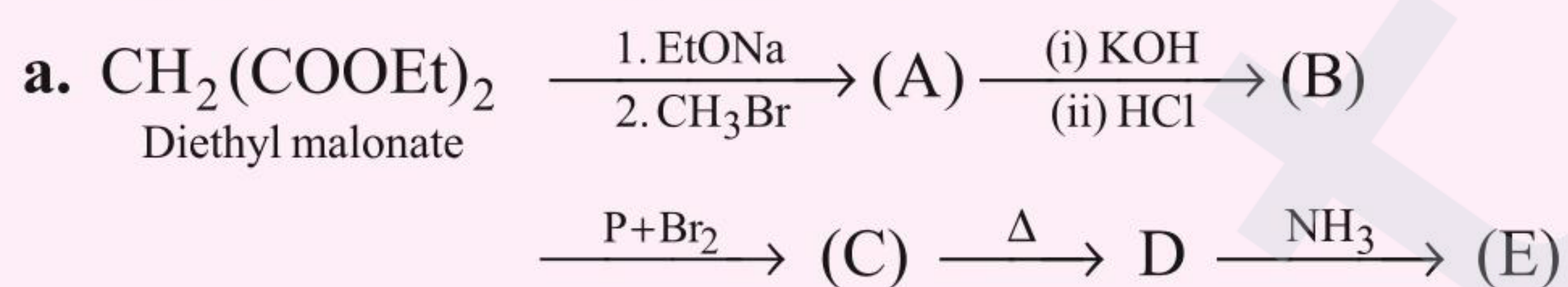
They include all enzymes, many hormones such as insulin from pancreas, thyroglobulin from thyroid gland (which produces thyroxine hormone), antibodies (responsible for allergies), haemoglobin (which transports oxygen from blood to the muscles), fibrinogen (which is converted into the insoluble protein fibrin and thus causes clotting of the blood), albumin in eggs, etc. Their characteristic geometry is a result of various interactions between different sites in the same polypeptide chains. These interactions are:

- i. Intramolecular H-bonding
- ii. van der Waals interactions
- iii. Disulphide bridging
- iv. Dipolar interactions

Globular proteins may consist of a single polypeptide chain or may have several polypeptide chains called subunits or protomers. Each subunit has its own three-dimensional geometry. The various subunits are then held together by secondary forces (e.g., H-bonding and van der Waals interactions) which gives the molecule its overall spheroidal shape.

CONCEPT APPLICATION EXERCISE 9.2

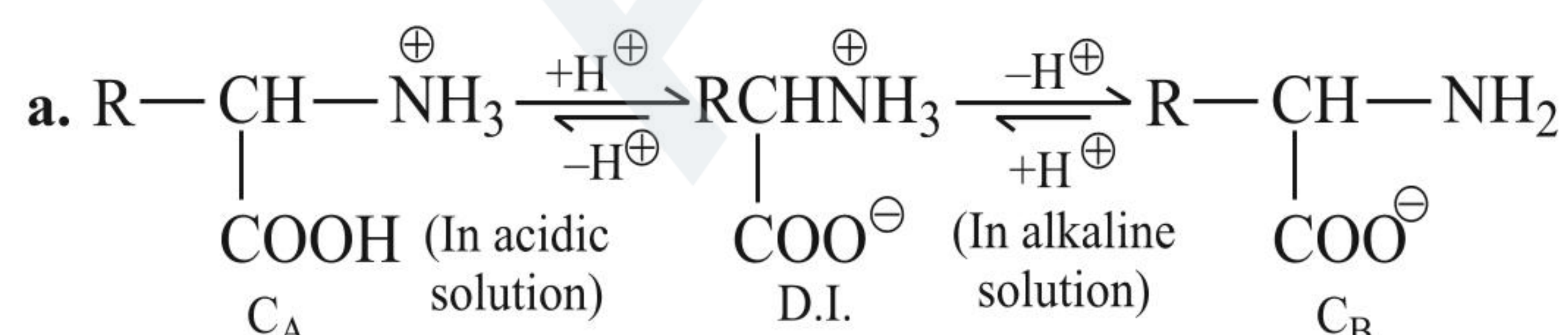
1. Complete the following reactions:



2. Explain the following tests for proteins.

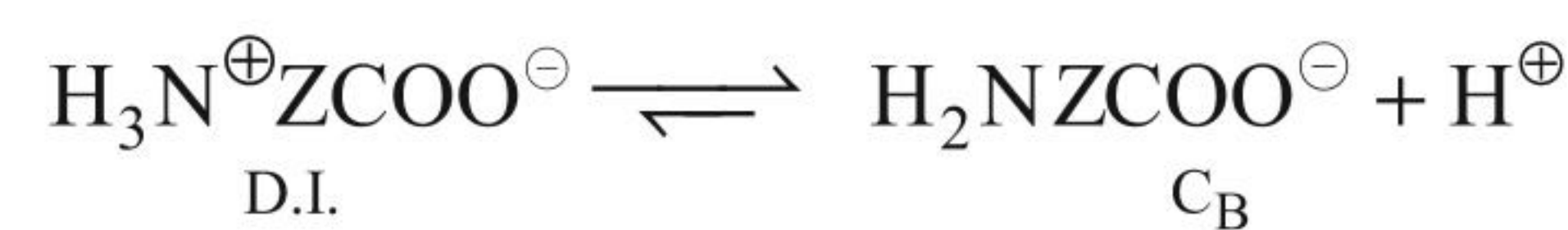
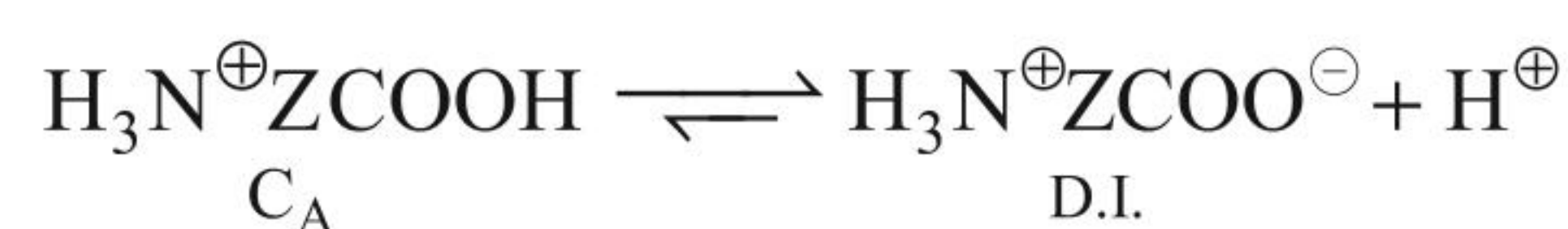
- a. Biuret reaction
- b. Xanthoproteic reaction
- c. Millon's test
- d. Ninhydrin test

9.4.3 ZWITTERION OR AMPHOLYTE OR DIPOLAR ION OR INTERNAL SALT



Isoelectric point: The pH at which D.I. does not migrate in electric field.

b. $\text{pH}_i = \left(\frac{\text{p}K_1 + \text{p}K_2}{2} \right)$



$$K_1 = \frac{[\text{D.I.}][\text{H}^\oplus]}{[\text{C}_\text{A}]}, \quad K_2 = \frac{[\text{C}_\text{B}][\text{H}^\oplus]}{[\text{D.I.}]},$$

$$\text{C}_\text{A} = \frac{[\text{D.I.}][\text{H}^\oplus]}{K_1}, \quad \text{C}_\text{B} = \frac{K_2[\text{D.I.}]}{[\text{H}^\oplus]}$$

At isoelectric point (pH_i), D.I. is maximum since the net charge is zero.

$$\therefore [\text{C}_\text{A}] = [\text{C}_\text{B}] \quad \frac{[\text{D.I.}][\text{H}_i^\oplus]}{K_1} = \frac{K_2[\text{D.I.}]}{[\text{H}_i^\oplus]}$$

$$\therefore [\text{H}_i^\oplus]^2 = K_1 K_2, \quad 2\text{pH}_i = \text{p}K_1 + \text{p}K_2, \quad \text{pH}_i = \left(\frac{\text{p}K_1 + \text{p}K_2}{2} \right)$$

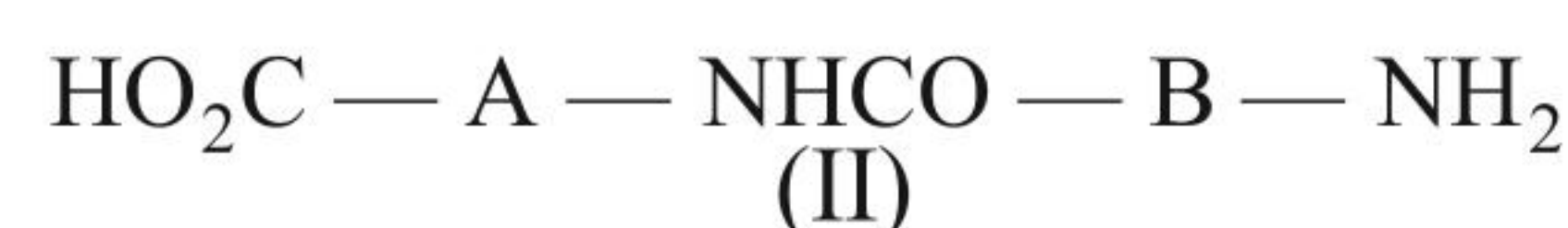
For glycine, $\text{p}K_1 = 2.4$ and $\text{p}K_2 = 9.6$.

$$\text{Hence } \text{pH}_i = \frac{2.4 + 9.6}{2} = 6.0$$

9.4.4 DETERMINATION OF THE POLYPEPTIDE SEQUENCE

The Primary Structure of Peptides

The primary structure of a peptide (or protein) is the sequence of amino acid residues in the molecule. First, let us consider a dipeptide composed of two different amino acids, (A) and (B). These may be combined in two different ways:



Inspection of either (I) or (II) shows that the two ends of each molecule are different. The 'amino-end' is said to be **N-terminal** and the 'carboxyl-end' is said to be **C-terminal**. The general method of writing the sequence of amino acids in a peptide (polypeptide or protein) is with the terminal amino group on the left. (I) is in accordance with this convention, but not (II), which should therefore be written as (II a). The peptides are then named as acylated derivatives of the terminal amino acid residue on the right hand side.

When the sequence of amino acids is not known, the symbols are enclosed in brackets and are separated by commas. When the sequence is known, the units are separated by dots or dashes or by arrows which indicate the direction of linkage from carboxyl to amino. Since the conventional way of writing peptide formulae has the terminal amino group on the left [see (I) and (II a)], the arrows will point left-to-right. A terminal amino group may be indicated by H and a terminal carboxyl group by OH. Finally, carbonamido groups may be indicated by the addition of NH_2 to the symbol, e.g., asparagine and glutamine (these have proposed alternatives): Asp NH_2 (Asn) and Glu NH_2 (Gln). Also, a proposed alternative for tryptophan is Trp. The following formulae illustrate the conventions:

(Ala, Gly, Tyr) Thr. (Val, Arg) Ala. Glu. Val or

H.Ala. Glu. Val. OH or Ala $\rightarrow$ Glu $\rightarrow$ Val or Ala — Glu — Val

Returning now to the problem of amino acid sequence, it can be shown that, in general, for n different acids $n!$ different combinations are possible. Furthermore, had not the common amino acids been all L acids, the total number of possible combinations would have been larger.

As a simple example, let us consider a tripeptide. The first thing to do in this case is to determine the nature of the amino acid residues. This is usually carried out by acid hydrolysis and chromatography. Suppose the amino acids are shown to be (A), (B), and (C). These can be written in six ($3!$) different combinations:

A.B.C A.C.B B.A.C C.A.B C.B.A

The problem then is: how do we ascertain which is the actual combination of the tripeptide under investigation? Inspection of the formulae shows that if we were able to determine the N-terminal amino acid (N-T-AA), then we would be able to group the six possibilities into three pairs, i.e., we would know that our tripeptide was either one or other of a pair. We would also be in this situation if we were able to determine the C-terminal amino acid (C-T-AA). Thus:

N-Terminal	C-Terminal
a. A.B.C and A.C.B	d. B.C.A and C.B.A
b. B.A.C and B.C.A	e. A.C.B and C.A.B
c. C.A.B and C.B.A	f. A.B.C and B.A.C

Since this results in different pairing, the determination of both N- and C-terminal groups will give the amino acid sequence of the tripeptide, e.g., if the N-T-AA determination showed that the tripeptide was in group (b) and the C-T-AA determination showed that the tripeptide was in group (d), the tripeptide is therefore B.C.A.

Now let us assume that the N- and C-T-AA methods are such that their application results in the removal of the respective terminal amino acid. In these circumstances, we would be left with different fragments according to the order of application (of the methods), e.g., for B.C.A:

- N-T-AA first: fragment C.A.
- C-T-AA first: fragment B.C.

By repeating either of these determinations, the amino-acid sequence is solved. Thus, the sequence may be determined by use of one method twice or by the use of each method once.

Now let us consider the tetrapeptide whose acids have been shown to be A, B, C, and D. There are 24 ($4!$) possible combinations (as shown). Suppose the N— and C—T—AA determinations showed, respectively, B and D.

A.B.C.D	B.A.C.D	C.A.B.D	D.A.B.C
A.B.D.C	B.A.D.C	C.A.D.B	D.A.C.B
A.C.B.D	B.C.A.D	C.B.A.D	D.B.A.C
A.C.D.B	B.C.D.A	C.B.D.A	D.B.C.A
A.D.B.C	B.D.A.C	C.D.A.B	D.C.A.B
A.D.C.B	B.D.C.A	C.D.B.A	D.C.B.A

The tetrapeptide is therefore B.A.C.D or B.C.A.D. As for the tripeptide, the fragments obtained will depend on the order of application:

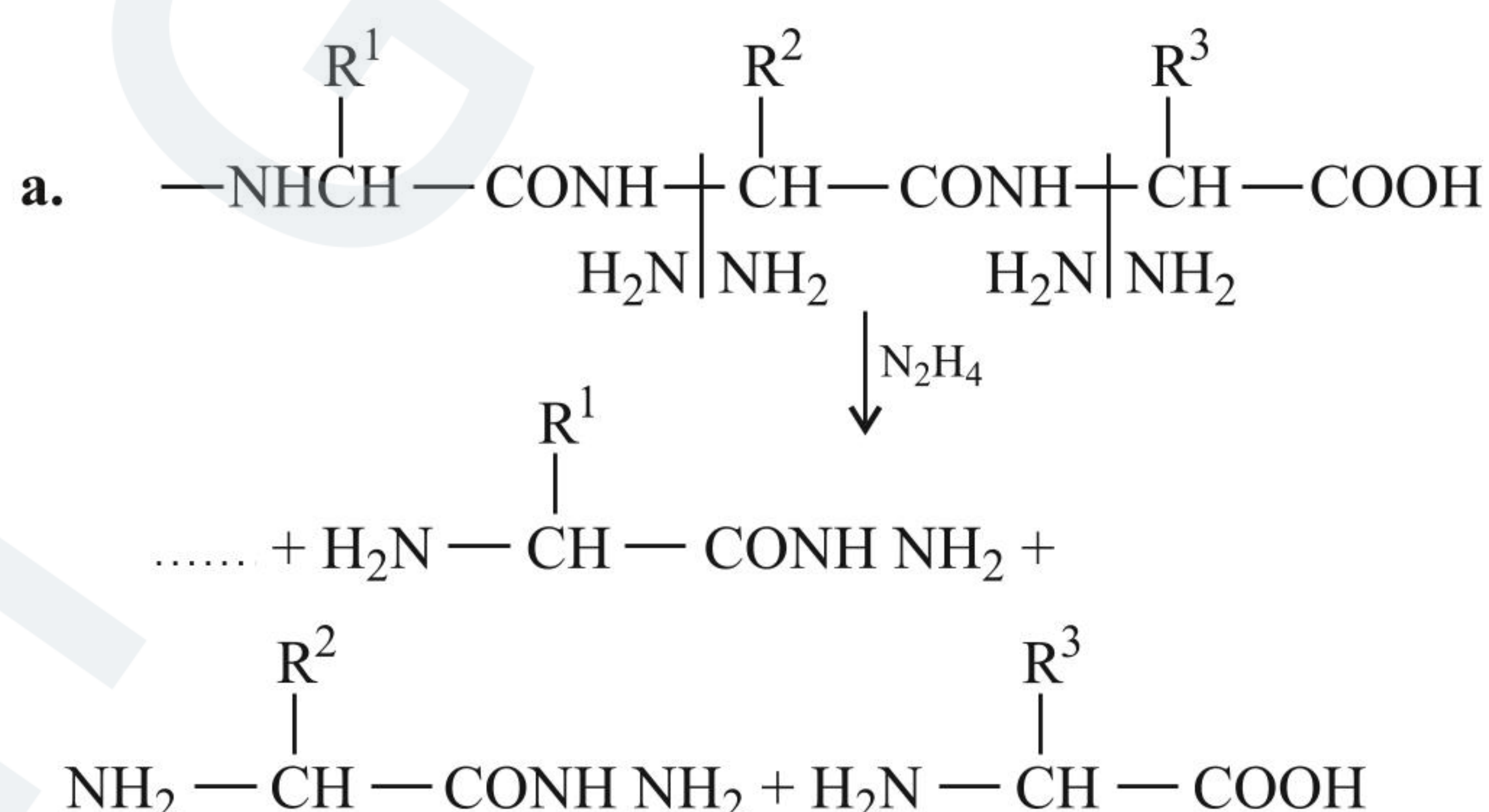
- N-T-AA first: fragments A.C.D or C.A.D

- C-T-AA first: fragments B.A.C or B.C.A

- Both N- and C-T-AA (irrespective of order): fragments A.C or C.A.

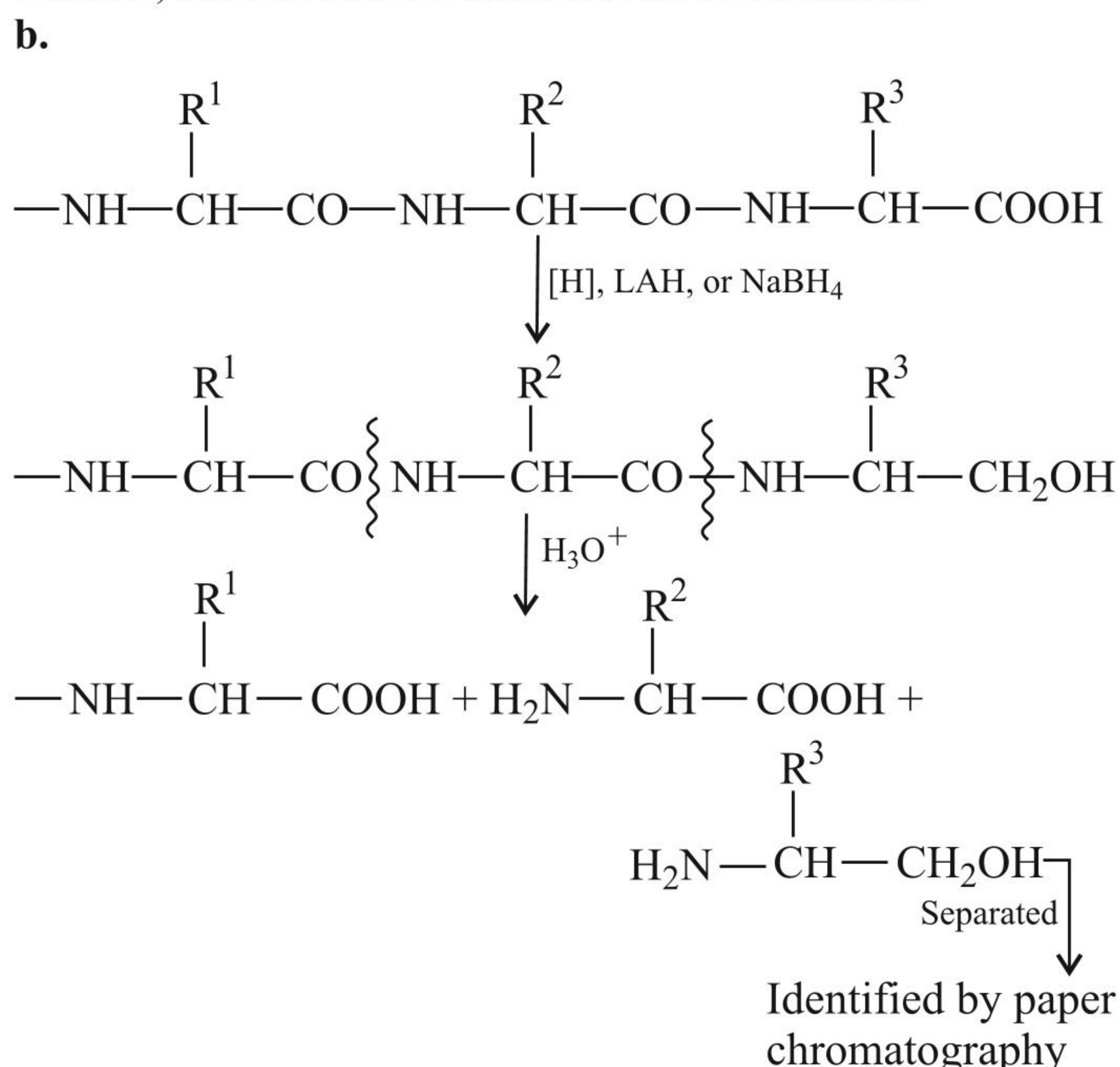
Hence, the amino acid sequence of the tetrapeptide may be determined by using either the N-T-AA or the C-T-AA method three times, or by a combination of these methods (also three operations). The general method of amino acid sequence analysis, however, does not use both end group analyses on the original peptide. Only one end group is determined and this is then followed by fragmentation of the peptide in at least two different ways. The smaller peptides are then subjected to amino acid sequence determination by end group analysis. In this way, the various small peptides 'overlap' and so it becomes possible to deduce the complete sequence of amino acids in the original peptide.

9.4.5 C-TERMINAL AMINO ACID DETERMINATION (Hydrazinolysis)



This reagent converts all AA residues except the C-terminal one into amino acid hydrazides.

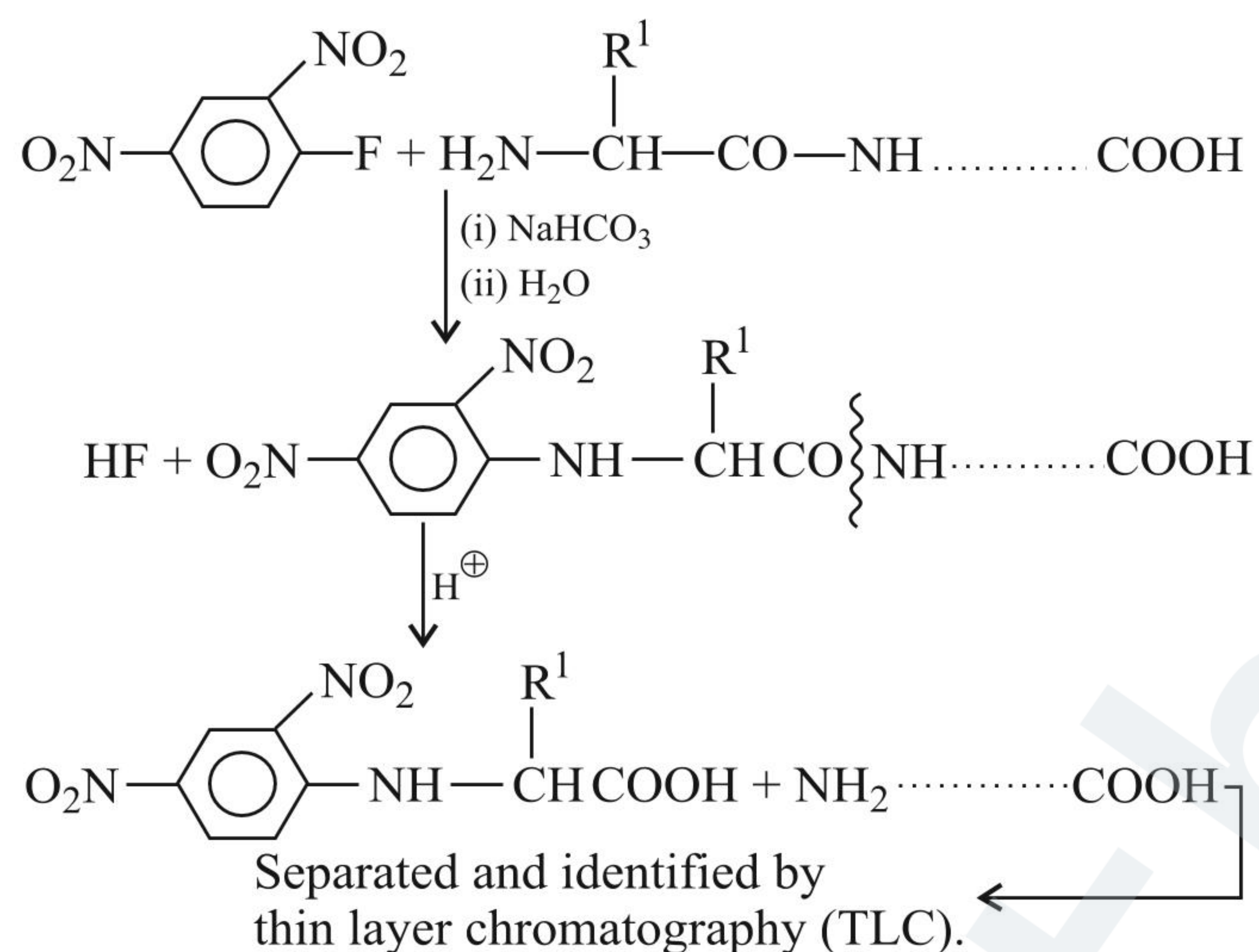
They are separated by column chromatography by using cation exchange resin. On elution, the strongly basic hydrazides are retained, but free AA is eluted and can be identified.



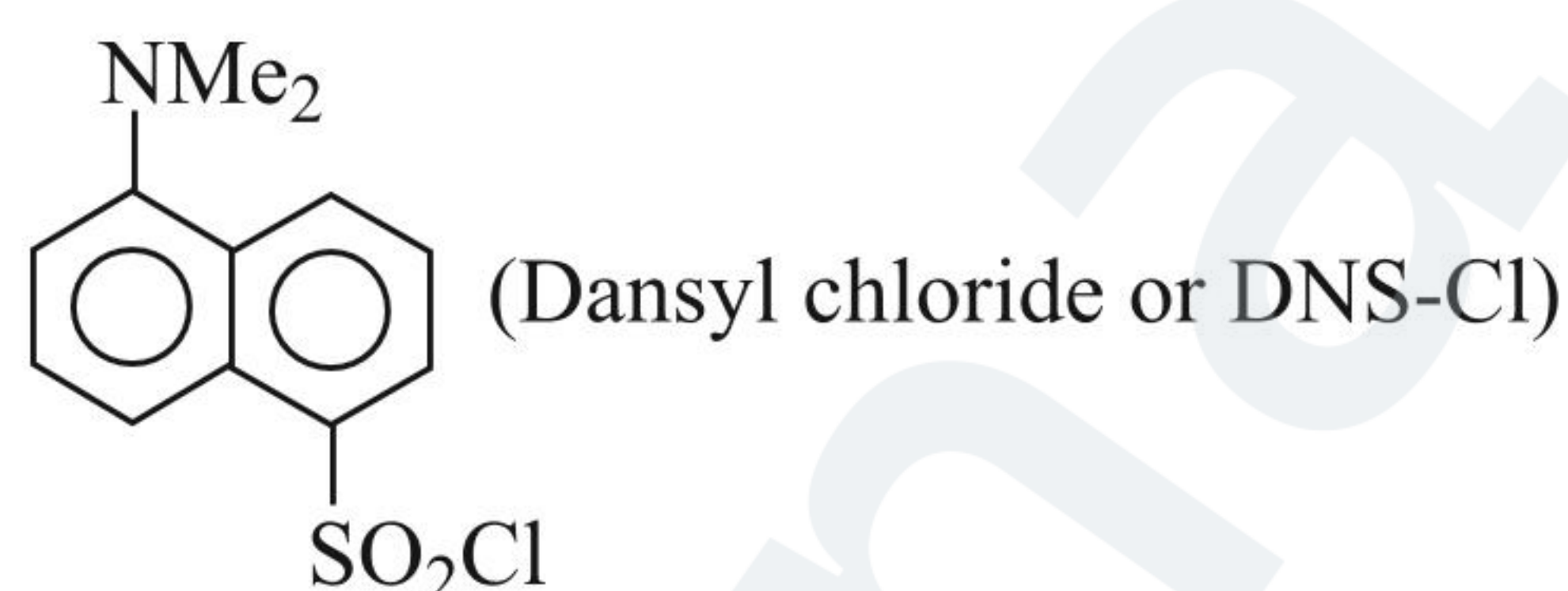
- c. The enzyme **carboxypeptidase** attacks proteins only at the end which contains the free (α -COOH) group. When this terminal AA residue is liberated, the new terminal free (—COOH) group is attacked by the enzyme and so on. Hence, by identification and quantitative determination of AA, their sequences can be established.

9.4.6 N-TERMINAL AMINO ACID DETERMINATION

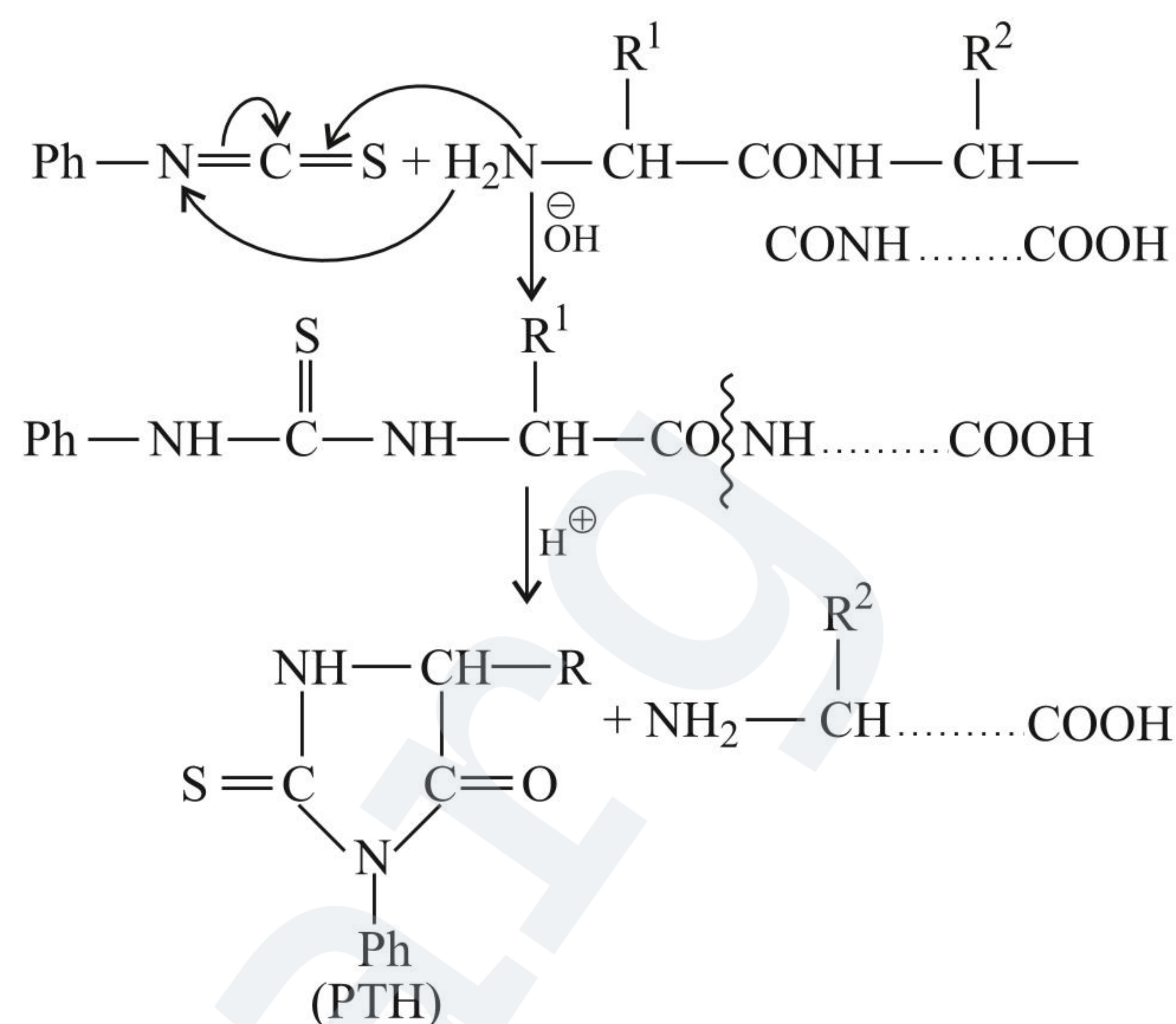
- a. **DNP method (Sanger's method):** FDNB (1-Fluoro-2,4-dinitrobenzene) reacts with (—NH_2) group in the presence of NaHCO_3 solution at room temperature to form DNP (2,4-dinitro phenyl) derivatives which are stable to acids. Hence hydrolysis of DNP-peptide produces DNP amino acid and a mixture of free AA.



- b. **Dansyl method:** Replace FDNB by DNS-Cl (5-dimethyl amino naphthalene-1-sulphonyl chloride, dansyl chloride) in the above equation. It is widely used nowadays because the dansyl group is fluorescent and can be detected by fluorimetric methods.



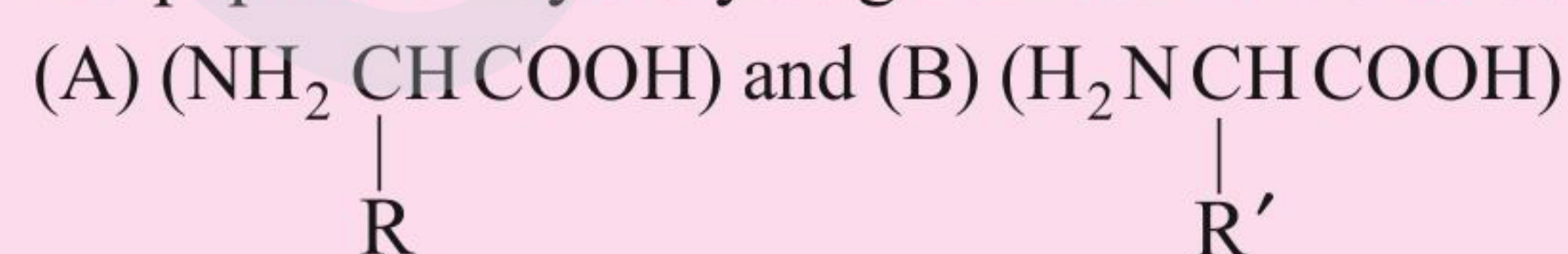
- c. Enzyme **leucine amino peptidase** attacks proteins only at the end which contains free amino group and proceeds to liberate, in succession, each new terminal AA. Hence, the estimation of AA sequence can be determined.
- d. **Edman method:** Phenyl isothiocyanate and the peptide form PTC-peptide (phenyl thiocarbamyl peptide) in the presence of dilute alkali.



(Phenyl thiohydantoin) (PTH is separated and identified by PC.)

ILLUSTRATION 9.13

A dipeptide on hydrolysis gives two amino acids.



The dipeptide is also hydrolysed by leucine amino peptidase enzyme giving amino acid (B). What is the structure of dipeptide?

Sol. The enzyme leucine amino peptidase hydrolyses N-terminal amino acid. So, (B) is N-terminal and (A) is C-terminal. Therefore, structure of dipeptide is:

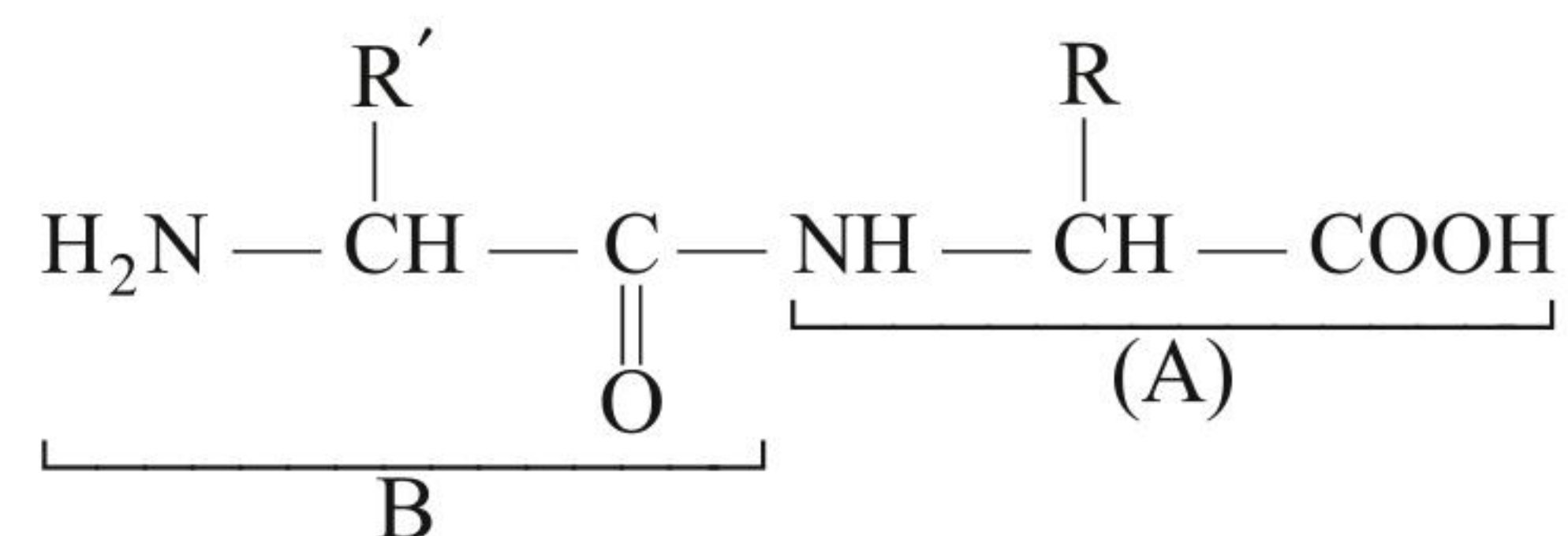
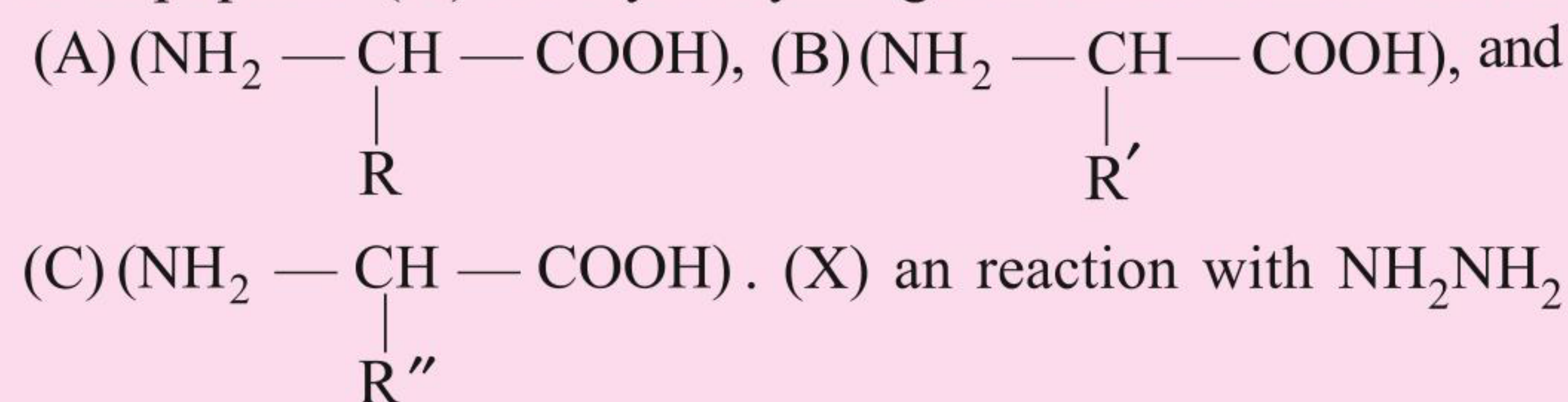


ILLUSTRATION 9.14

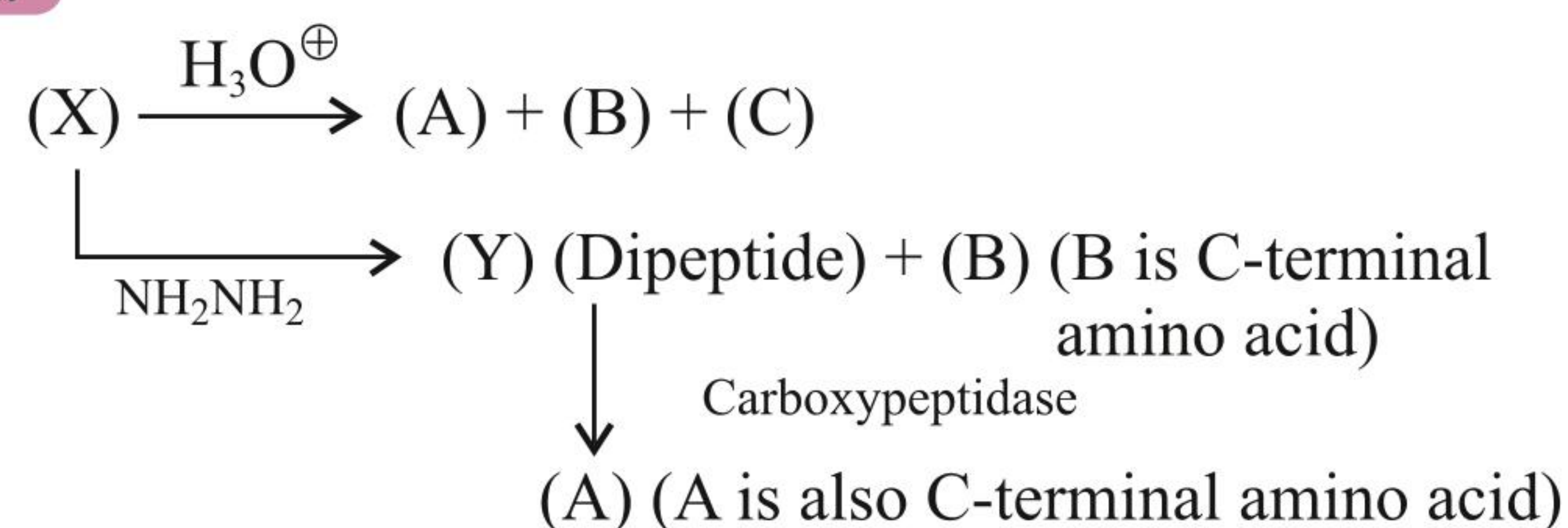
A tripeptide (X) on hydrolysis gives three amino acids



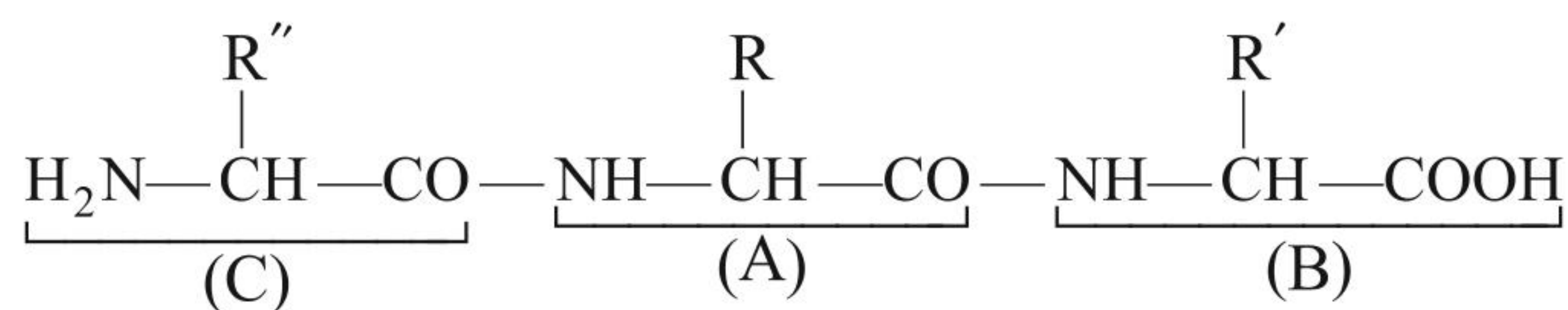
gives a dipeptide (Y) and amino acid (B).

The dipeptide (Y) is hydrolysed by carboxypeptidase enzyme and gives amino acid (A). What is the structure of (X)?

Sol.



From the above reaction, it is clear that the amino acid (C) is N-terminal. Hence the sequence is (C → A → B).



9.4.7 Enzymes

They are defined as biological catalysts and are globular proteins. However, some enzymes are also associated with some non-protein component called prosthetic group for their activity. These prosthetic groups could be either metal ions called cofactors or some small organic molecules called coenzymes. Coenzymes are derived from vitamins such as thiamine, etc.

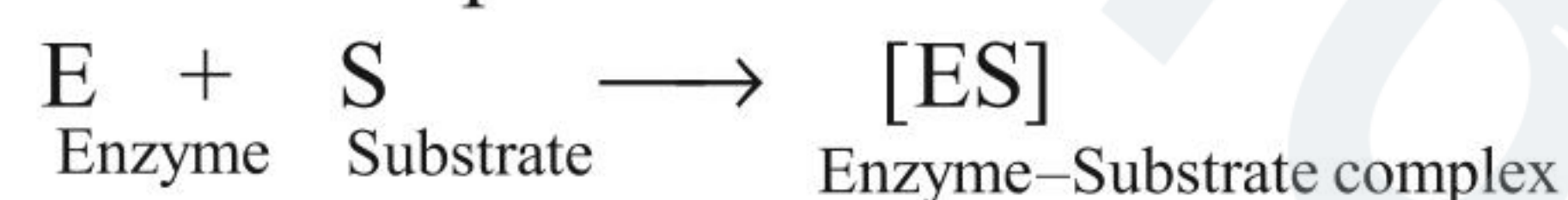
Example: α -Amylase hydrolyses α -linkage while emulsin hydrolyses β -linkage.

a. Properties of enzymes:

- Specificity, i.e., each enzyme catalyses only one reaction. For example, urease hydrolyses urea but not N-methyl urea.
- Efficiency: They are very efficient catalysts. They speed up the rate of a reaction by factors of upto 10^{20} , e.g., proteins present in our food are easily hydrolysed in our body by different enzymes.
- Small quantity: Only small amounts of enzymes can be highly efficient.
- Optimum temperature and pH: Enzyme-catalysed reactions occur in aqueous solution at pH = 7 and at physiological temperature of 37°C (310 K) and under 1 atm pressure.
- Enzyme inhibitors: The action of enzymes is controlled by a number of mechanisms and is inhibited by certain organic molecules called inhibitors.

b. Mechanism of enzyme action:

Step 1: Bonding of enzyme to the substrate (reactant) to form a complex.



Step 2: Product formation in the complex.



Enzymes are specific due to the presence of specific regions called active sites on their surface. These

active sites form weak bonds such as H-bonds and van der Waals attractions with the substrate molecules. Due to specific shape of active sites, only specific substrates fit into the sites like key and lock theory, and form enzyme-substrate complex. Once proper orientation has been achieved, substrate molecules react to form the products.

- Applications:** In the manufacture of beer and wine by fermentation of carbohydrates, sweet syrup from corn starch, production of cheese by coagulation of milk, etc.
- Diseases caused by enzyme deficiency:** Congenital disease **phenylketoneurea** is caused by the deficiency of an enzyme called **phenylalanine hydroxylase**. The disease results through the accumulation of compounds in the body leading to brain damage and mental retardation in children. The disease can be cured by feeding the patients with a diet which is low in phenylalanine content.

Another disease which is caused by the deficiency of the enzyme **tyrosinase** is **albinism**. Moreover, it has been possible to check heart attacks by using the enzyme **streptokinase** which dissolves the blood clot.

Disease **sickle cell anaemia** is caused by **defective haemoglobin**.

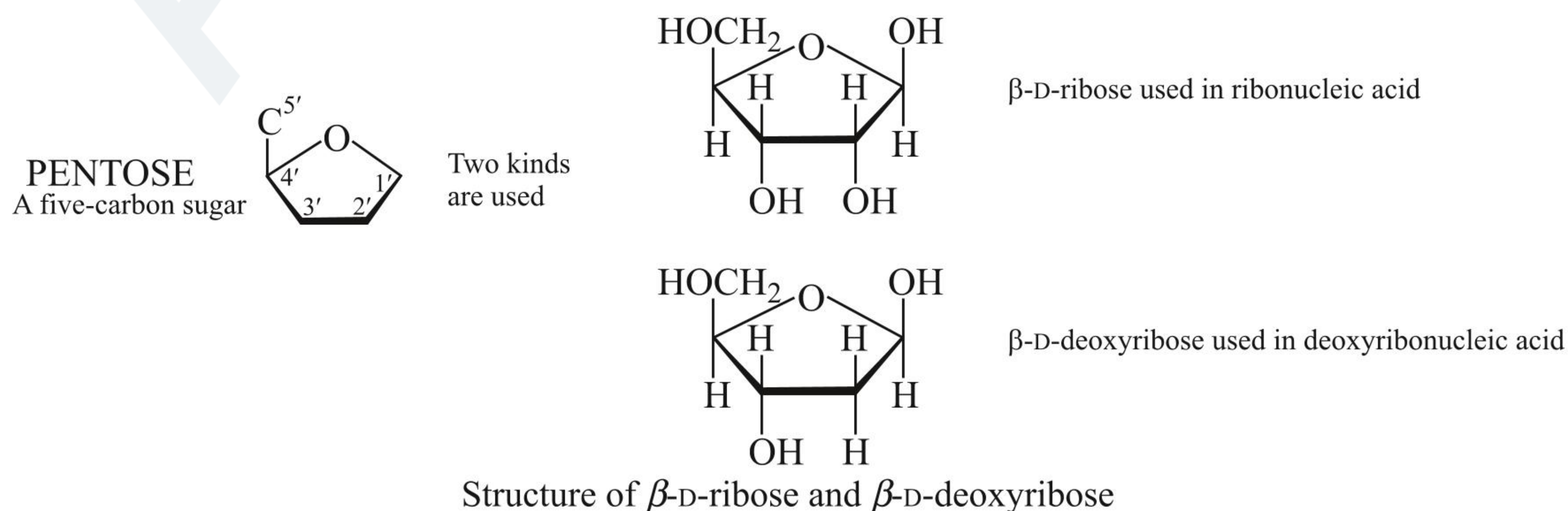
9.5 NUCLEIC ACIDS

All living cells contain nucleoproteins. These are the substances built of proteins in combination with biopolymers of another type, the nucleic acids. There are mainly two types of nucleic acids: the **deoxyribonucleic acids (DNA)** and **ribonucleic acids (RNA)**. Nucleic acids are basically long-chain polymers (polynucleotides) of nucleotides. The proteins possess a polyamide chain; nucleic acids, on the other hand, contain a polyphosphate ester chain.

In higher cells, the DNA is localised largely in the nucleus inside the chromosome. In addition, a small amount of DNA is also available in the cytoplasm. Here, it is found in mitochondria and chloroplasts. RNA is also found both in nucleus and in cytoplasm. DNA as the chief source of genetic information is copied into RNA molecules (transcription). The **Code** for specific amino acid sequences is found in the sequence of nucleotides. Proteins are then synthesised in a process that involves the translation of RNA.

- Chemical composition of nucleic acid (primary structure):** Full hydrolysis of DNA (or RNA) gives a pentose sugar (ribose in RNA and deoxyribose in DNA), two kinds of heterocyclic nitrogenous bases (purines and pyrimidines), and phosphoric acid.

Deoxyribose is different from ribose in not having an —OH on C-2 (Fig. 9.7).



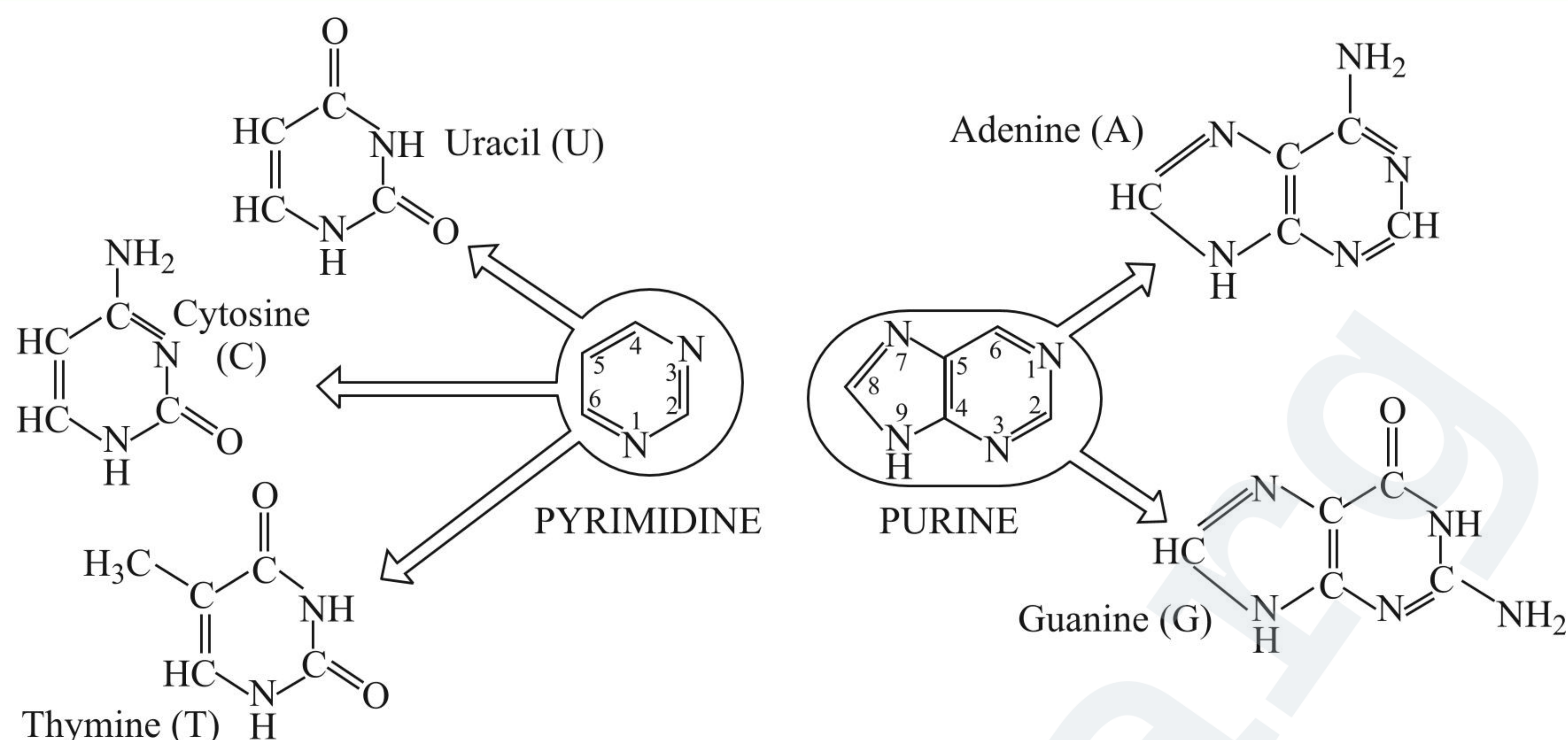
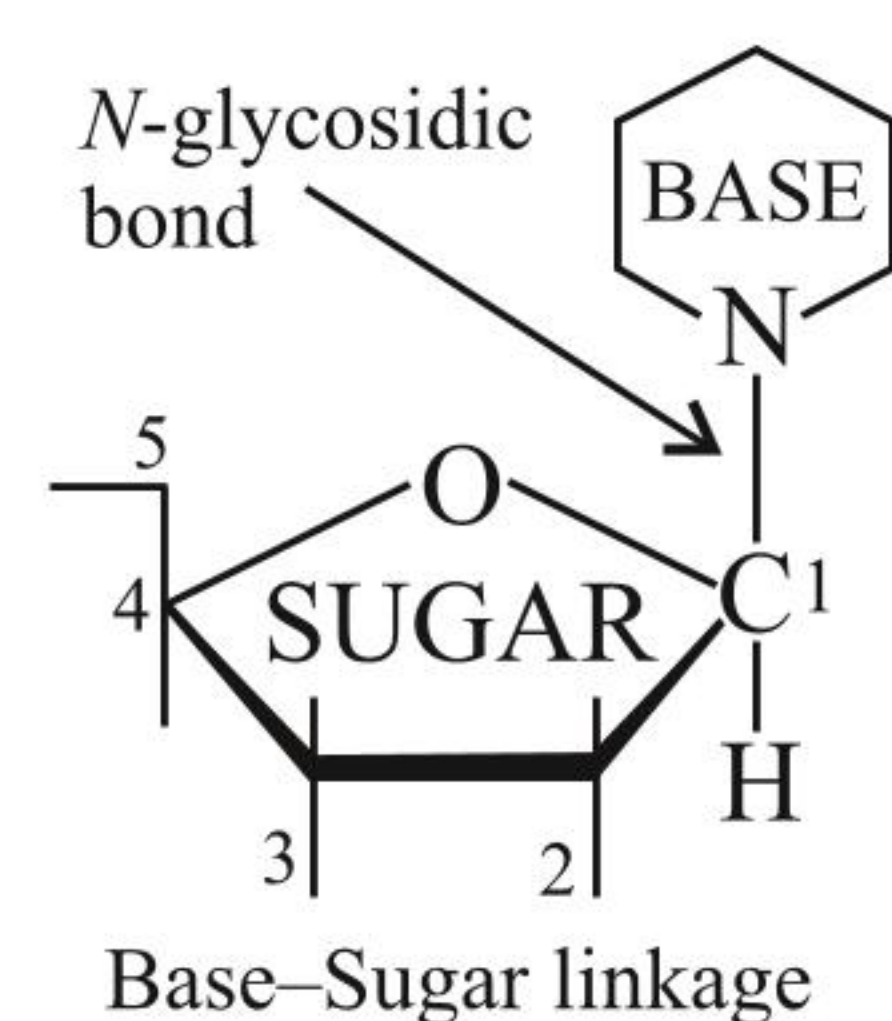


Fig. 9.7 Purine and pyrimidine bases

As shown in Fig. 9.7, the pyrimidines possess a single heterocyclic ring while purines have got two fused rings. DNA possesses the purine bases [adenine (A) and guanine (G)] and pyrimidine bases [thymine (T) and cytosine (C)]; while RNA contains uracil (U) instead of thymine (T). It is to be noted that there are two key structural differences between DNA and RNA: (1) DNA contains deoxyribose while RNA has ribose sugar; (2) DNA has thymine while RNA contains uracil.

- b. Nucleosides:** Nucleosides are the N-glycosides of purine or pyrimidine bases with pentose sugars, i.e., base + sugar = nucleoside.

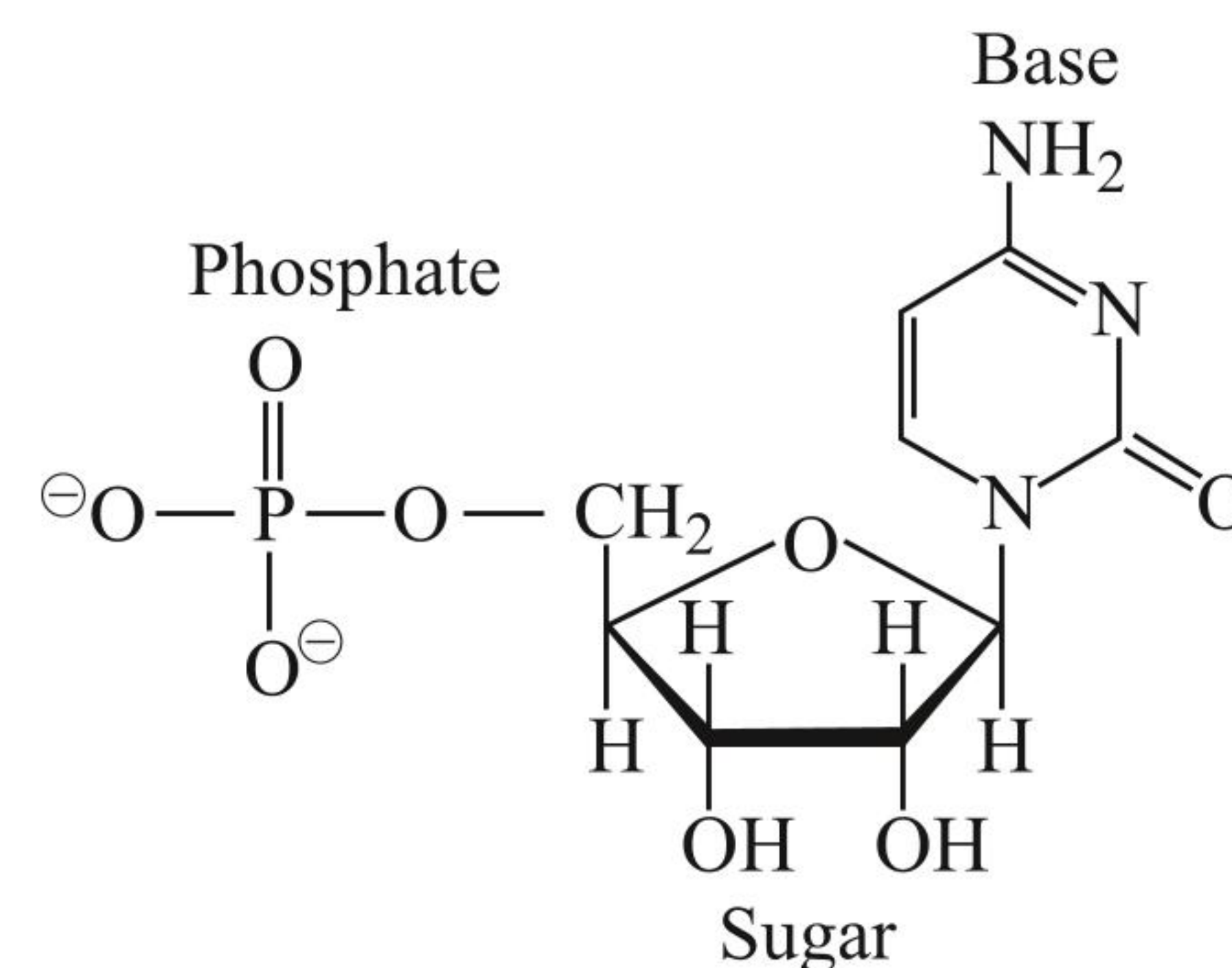


Base	Abbreviation	Nucleoside
Adenine	A	Adenosine
Guanine	G	Guanosine
Cytosine	C	Cytidine
Thymine	T	Thymidine
Uracil	U	Uridine

The sugar carbons are primed 1', 2', 3', etc., in nucleosides to differentiate them from the bases. The purine or

pyrimidine bases are attached to position 1 of pentoses through N-glycosidic linkages.

- c. Nucleotides:** A nucleotide is a phosphate ester of nucleoside and comprises a purine or pyrimidine base, five-carbon sugar, and one or more phosphate groups (base + sugar + phosphate = nucleotide).



The nucleotides have three capital letters abbreviations preceded by d- for deoxy series, e.g.,

AMP = Adenosine monophosphate
dAMP = Deoxyadenosine monophosphate
ATP = Adenosine triphosphate
UDP = Uridine diphosphate, etc.

Nucleotides are linked together by phosphodiester linkages between 5' and 3' carbon atoms of the pentose sugar. The process of formation of a characteristic dinucleotide is depicted in Fig. 9.8.

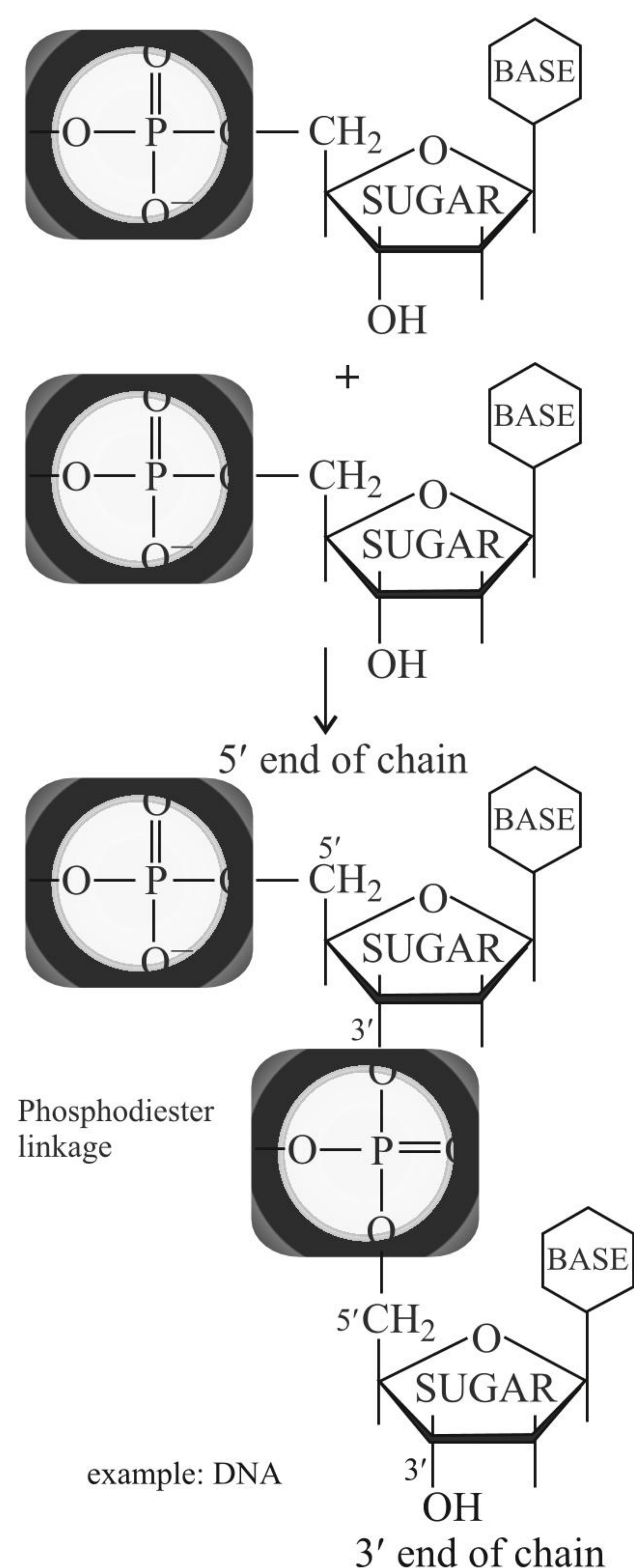
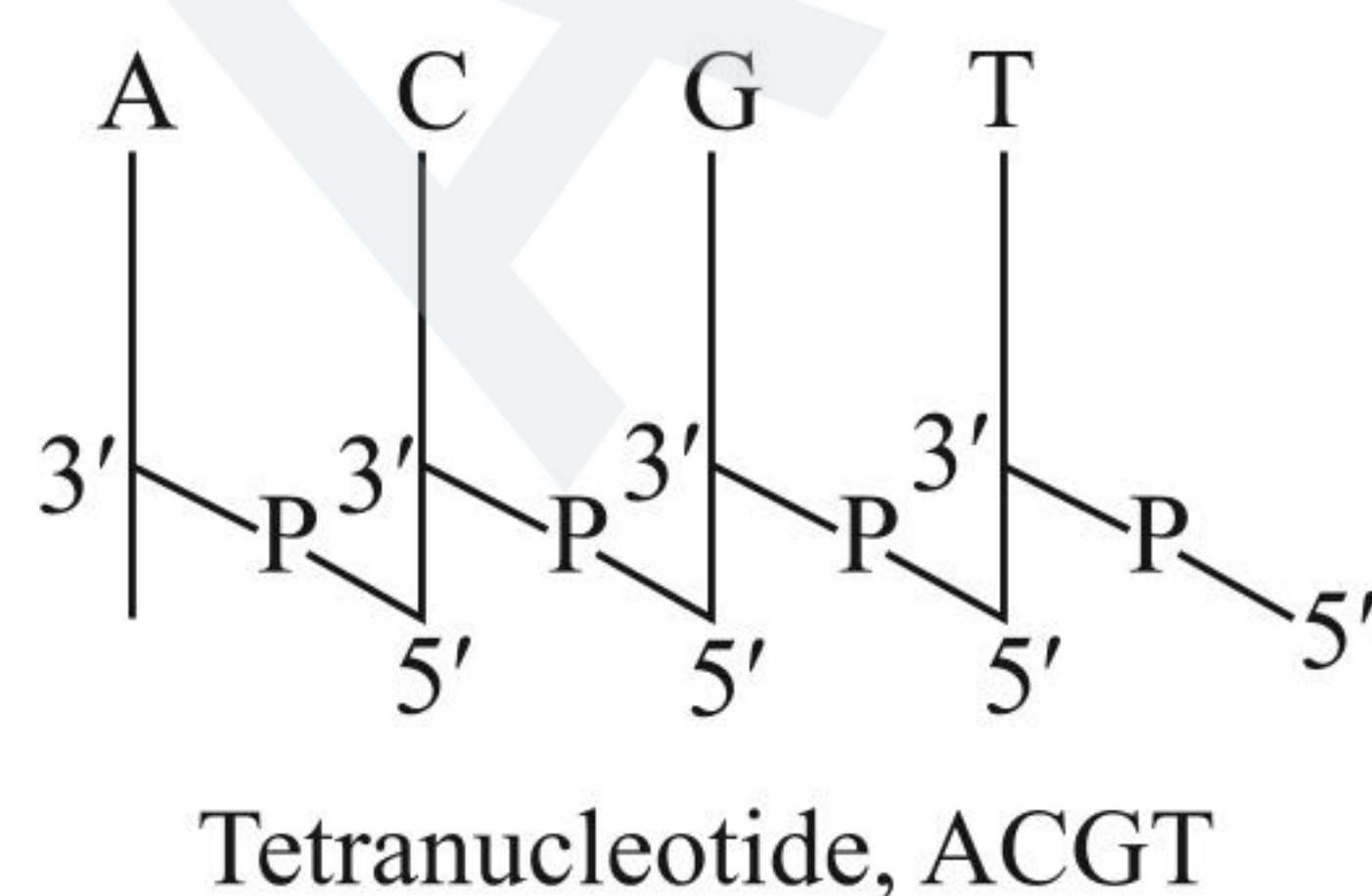


Fig. 9.8 Formation of a dinucleotide

A nucleic acid chain is usually abbreviated by a one-letter code with the 5' end of the chain written at the left. For example, tetranucleotide possessing adenine, cytosine, guanine, and thymine bases from 5' end to 3' end is depicted as ACGT.

The backbone comprises alternating sugar and phosphate bonds. It is tremendously time-consuming to give the full structures of these oligonucleotides. For simplification, the phosphate bond is depicted by the symbol 'P' and sugar is derived by the simple Fischer projection. So, the tetranucleotide ACGT may be drawn as given below:



Nucleic acids are the polymers of nucleotides which in turn consist of a base a pentose sugar and phosphate moiety. Nucleic acids are responsible for the transfer of characters from parents to offsprings. There are two types of nucleic acids **DNA** and **RNA**. DNA contains a five carbon sugar molecule called **2-deoxyribose** whereas RNA contains ribose. Both DNA and RNA contain adenine, guanine and cytosine. The fourth base is thymine in DNA and uracil in RNA. The structure of DNA is a double strand whereas RNA is a single strand molecule. DNA is the chemical basis of heredity and have the coded message for proteins to be synthesised in the cell.

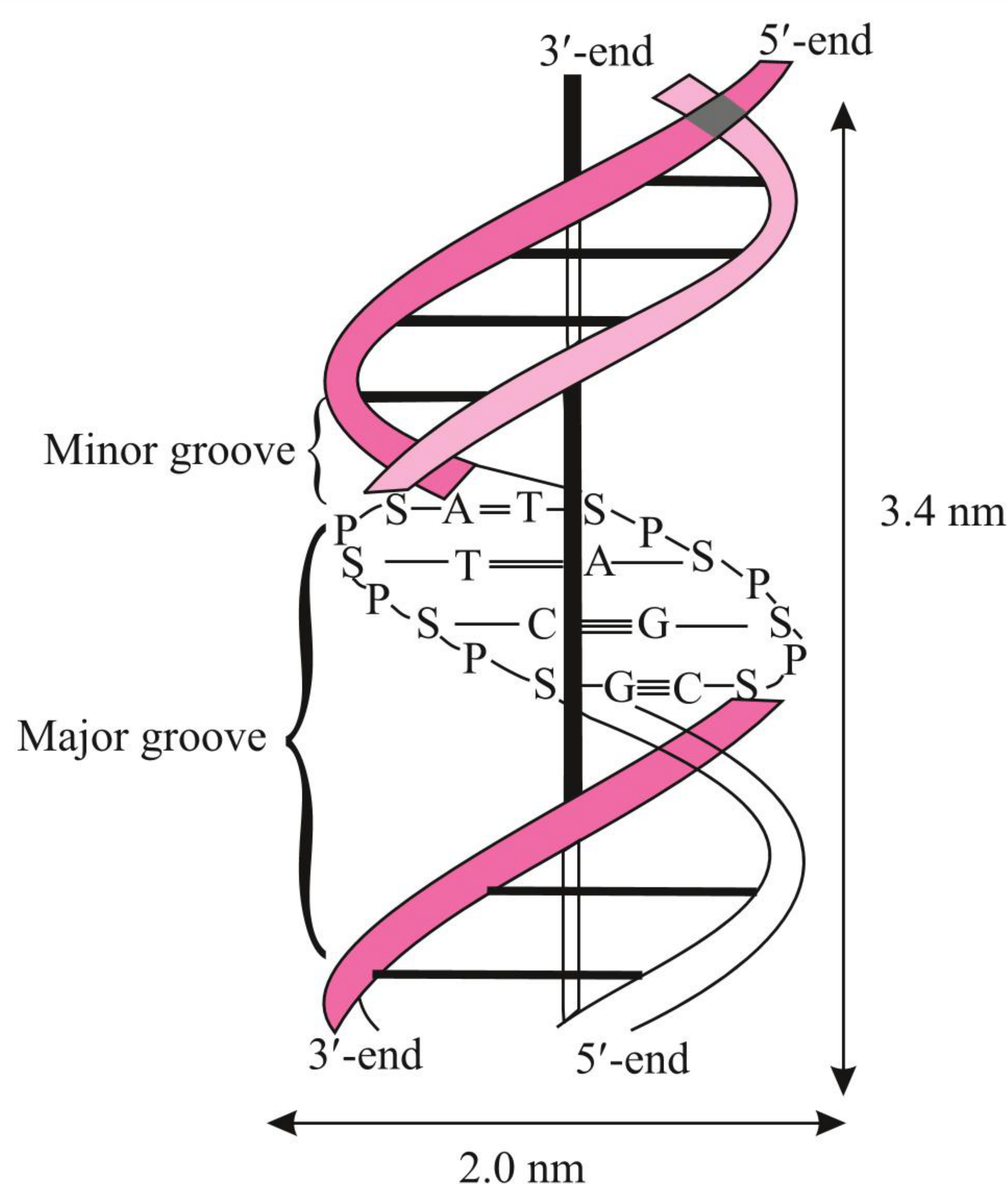
d. DNA: A double helix

E. Chargaff established that various species had varying base compositions in DNA. Nonetheless, in all cases the amount of adenine was equal to that of thymine ($A=T$). Further, the amounts of cytosine and guanine were also found to be equal ($G=C$). Hence, the total amount of purines was equal to the total amount of pyrimidines ($A + G = C + T$). On the other hand, the AT/CG ratio deviates significantly between species, e.g., this ratio is 1.52 in man, whereas in *E. Coli* it is just 0.93.

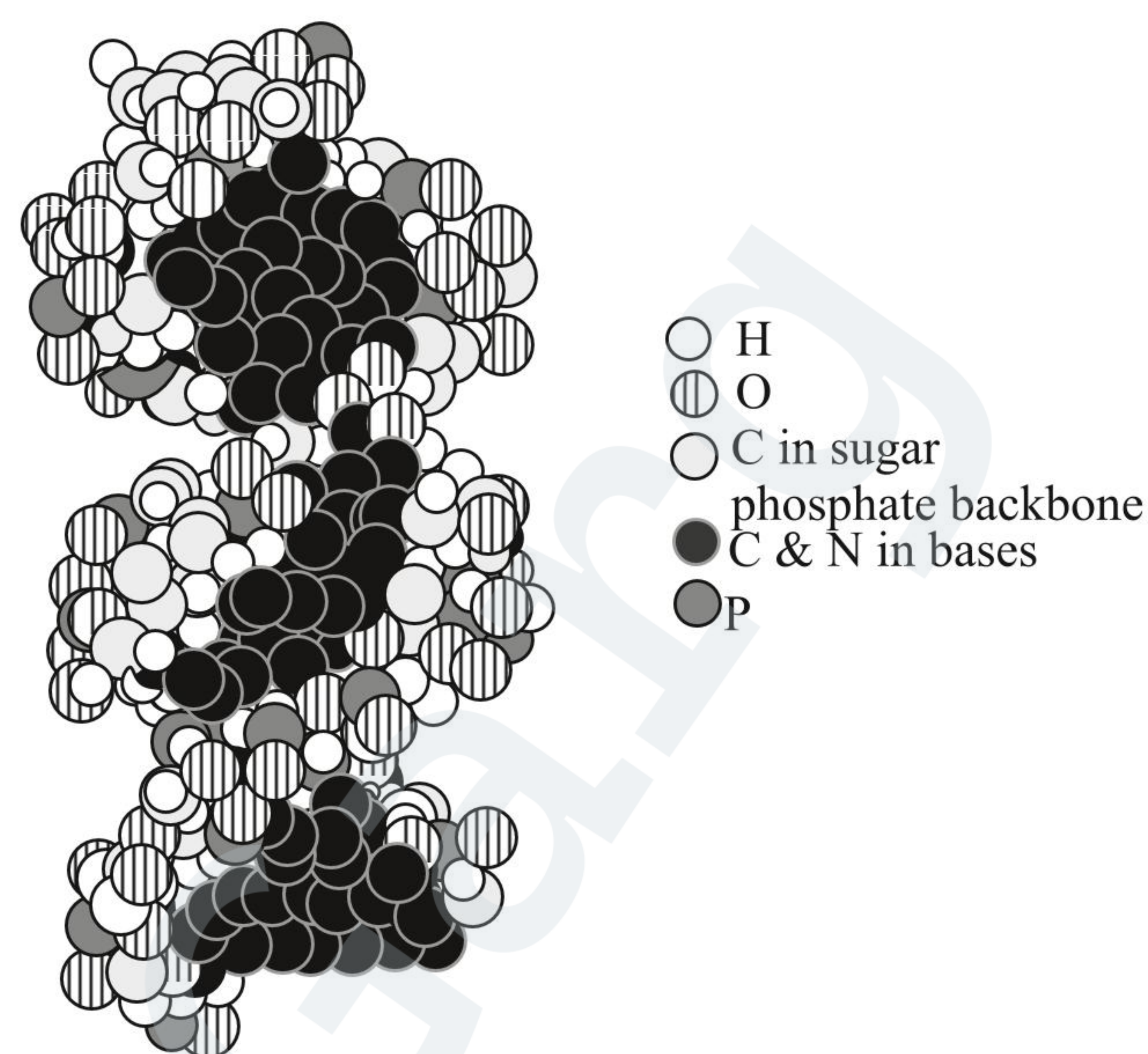
In 1953, using the X-ray diffraction studies of DNA, J.D. Watson and F.H.C. Crick hypothesised a **double helical structure for DNA** that explained not just the base equivalence ($A = T$; $G = C$) but also other properties of DNA, specifically its duplication in a living cell (replication). The double helical structure of DNA is presented in Fig. 9.9.

The double helix comprises two right-handed helical polynucleotide chains coiled around a common central axis. These two strands are antiparallel, i.e., their ($5' \rightarrow 3'$) phosphodiester linkages are in reverse directions. Helix has the bases stacked inside them in planes perpendicular to the helical axis. It appears like a heap of flat plates held together by two ropes of sugar-phosphate polymeric backbone running along outside the stack.

The two strands are joined by hydrogen bonds, depicted as black rods in Fig. 9.9. Only two base pairs, i.e., AT and CG fit into this structure. Three hydrogen bonds are formed between C and G ($C \equiv G$) and two are formed between A and T ($A = T$). Consequently, CG base pair possesses more stability in comparison to AT base pair (Fig. 9.9). The two complementary base pairs of DNA, i.e., ($T-A$) and ($C-G$) with their hydrogen bonds are drawn in the figure. Apart from hydrogen bonds, other forces, e.g., hydrophobic interactions between the stacked bases, are also accountable for the stability and continuance of double helix.



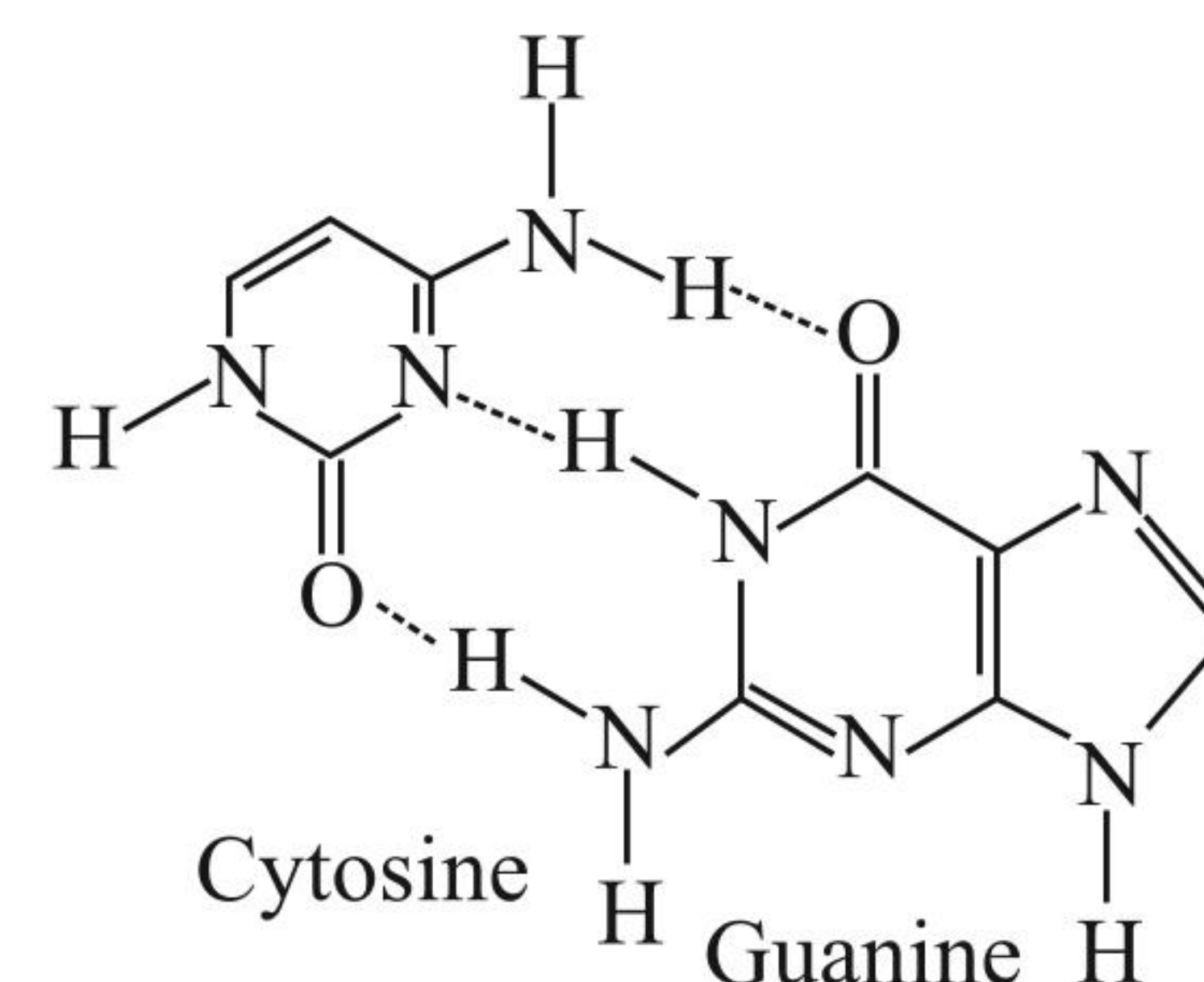
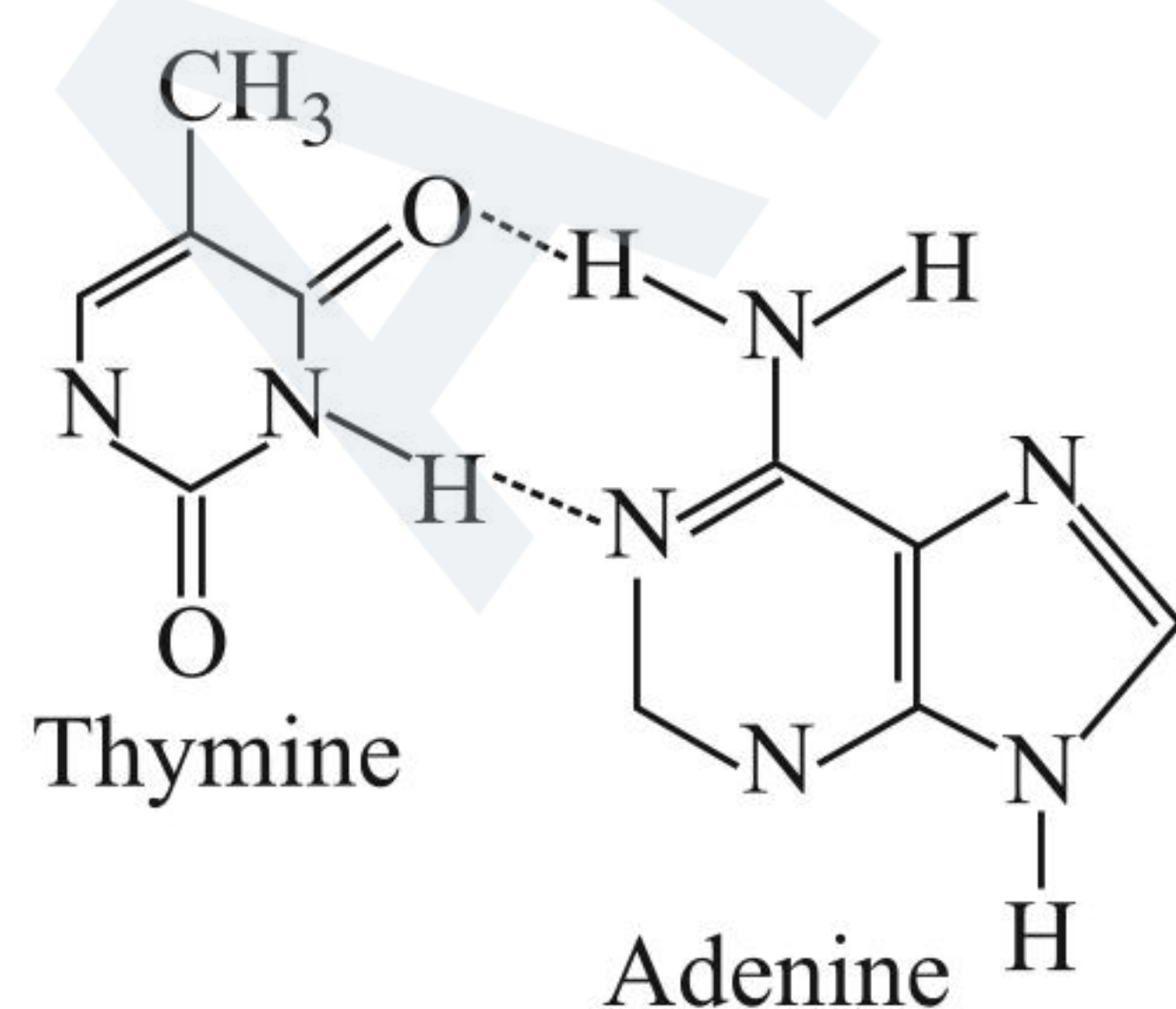
(a) Diagrammatic representation



(b) Space filling model

Fig. 9.9 Double helical structure of DNA

The diameter of double helix is 2 nm. The double helical structure gets repeated at intervals of 3.4 nm (one complete turn) corresponding to 10 base pairs. Two types of grooves, one major and one minor, are apparent in the structure. DNA helices may be both right handed as well as left handed. The β -conformation of DNA possessing the right-handed helices is most stable. When heated, the two strands of DNA break up from each other (called melting) and on cooling these again hybridise (known as annealing). Melting temperature (T_m) is the temperature at which the two strands get separated entirely. It is specific for each specific sequence. Till now we have been discussing the secondary structure of DNA. In the secondary structure of RNA, only single-stranded helices are present. At higher levels, we deal with the manner in which these molecules are linked to proteins: folded and supercoiled to form chromatin and chromosomes. With the help of such structures, it is easy to explain how four meters of DNA can be stacked inside a single cell.

**ILLUSTRATION 9.15**

The two samples of DNA, A and B have melting temperatures (T_m) 340 and 350 K, respectively. Can you draw any conclusion from this data regarding their base content?

Sol. The B sample of DNA having higher T_m must be having more GC content as compared to sample A, since GC base pair having three hydrogen bonds (as compared to AT base pair having only two hydrogen bonds) results in stronger bonding.

ILLUSTRATION 9.16

In *E. coli* DNA, the AT/GC ratio is 0.93. If the number of moles of adenine in its DNA sample is 465,000, calculate the number of moles of guanine present.

Sol. The number of moles of adenine should be equal to those of thymine, $(A + T) = 930,000$. Since, $A + T / G + C = 0.93$, $(G + C) = 1,000,000$. Therefore, the number of moles of guanine should be $1,000,000/2 = 500,000$.

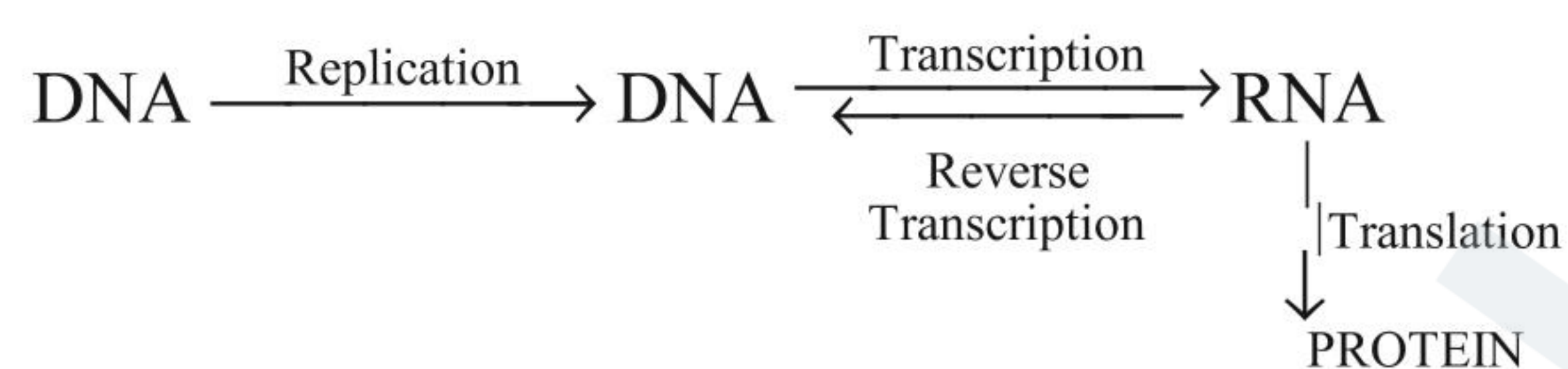
9.5.1 HEREDITY: THE GENETIC CODE

Nucleic acids are the controllers of heredity on the molecular level. The double helix of DNA is the store house of the organism's hereditary information. This information is coded in the form of a sequence of bases along the polynucleotide chain. As the DNA comprises only four dissimilar bases, the genetic message can be linked to a language having just four letters A, C, G, and T.

The DNA must safeguard this information and utilise it in the below given manner:

- DNA molecules can undergo duplication, i.e., can synthesise other DNA molecules matching with the original; this procedure is called **replication**.
- A single strand of DNA can function as a template on which a molecule of RNA is synthesised in a definite manner. This procedure is known as **transcription**.
- The RNA molecule in turn directs the synthesis of specific proteins that are distinguishing factors of each type of organism. This process is known **translation**.

These concepts make up the central doctrine of molecular biology and have been summarised by Francis Crick in the below given diagram.



The word *transcription* is used as a synonym for RNA synthesis in molecular biology and *translation* as a synonym for protein synthesis. Translation is unidirectional but transcription may sometimes be reversed, i.e., RNA is copied into DNA. Such type of **reverse transcription** takes place during the life cycle of some retroviruses.

Thus, we can deduce that the base sequence in DNA indirectly controls the sequence of amino acids in the protein. Since the protein molecule can hold a maximum of 20 various types of amino acids, it is similar to a large sentence written in a language of 20 letters. However, the hereditary message is written in a language of only four letters; it is written in a code with each word of three letters (triplet: codon) representing a specific amino acid. In order to fully comprehend the genetic code, it is fitting that we first learn about replication and transcription.

9.5.2 REPLICATION

In the DNA double helix, the sequence of bases in one chain is complementary to the sequence in the other chain, so one controls the other.

At the moment of cell division (mitosis), the two strands of the DNA double helix partially unwind and each functions as a template for the synthesis of a new DNA molecule (Fig. 9.10). Following the base pairing rules, in DNA replication A pairs with T and G pairs with C. Hence, each daughter molecule is the precise replication of the parent molecule. Also, DNA replication is

semi-conservative, i.e., just half of the parental DNA is conserved and only one strand is synthesised. It occurs only in the 5' → 3' direction.

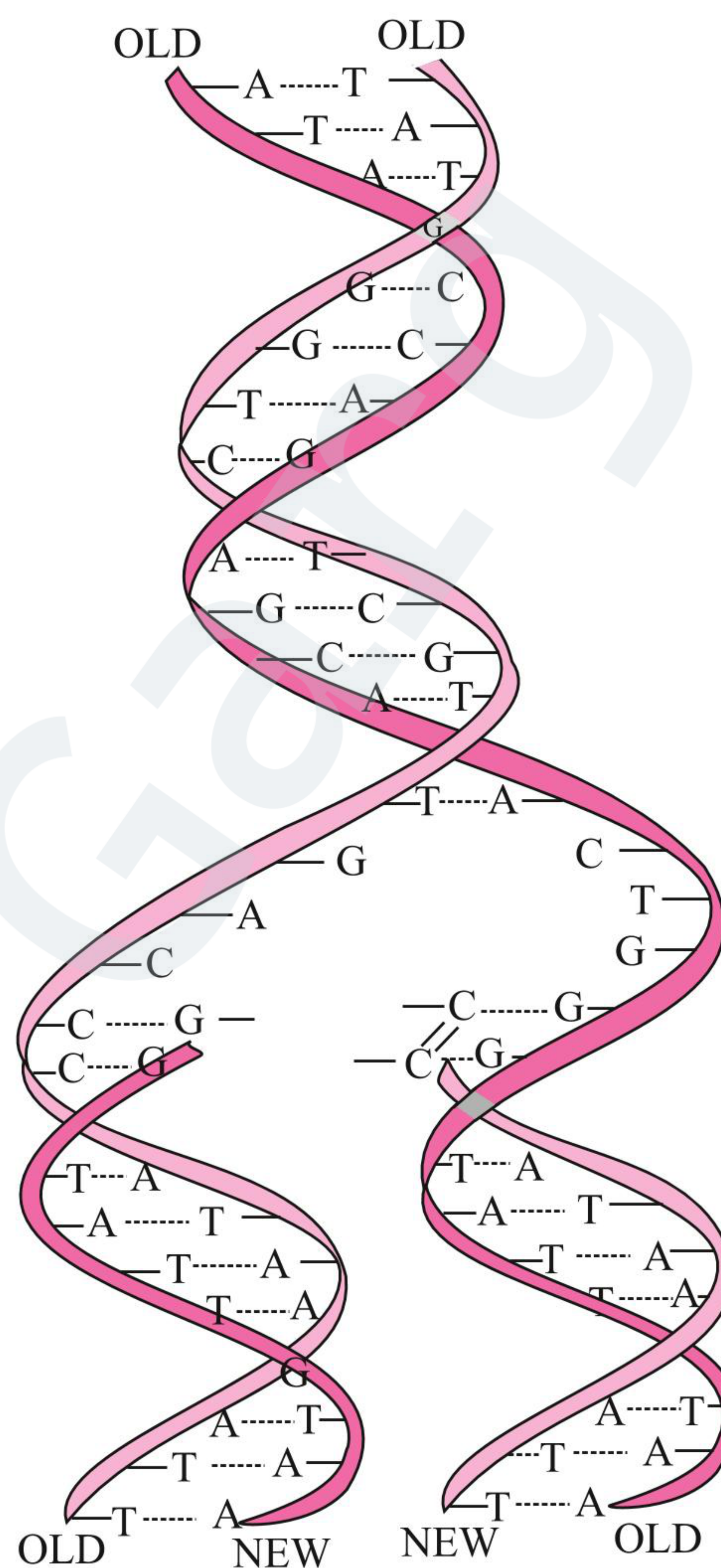


Fig. 9.10 Mechanism of DNA replication

9.5.3 TRANSCRIPTION

The process of transcription matches DNA replication. The double helix of DNA partly uncoils and a chain of RNA is formed on one of the two strands. In this case, a ribose sugar is included against a deoxyribose moiety of the parent DNA strand and a uracil is added opposite each adenine of DNA. The freshly formed chain of RNA is complementary to a section or strand of the DNA chain. There are three types RNA: messenger RNA (mRNA), transfer RNA (tRNA), and ribosomal RNA (rRNA). The mRNA takes a message to the ribosome where protein synthesis occurs.

9.5.4 PROTEIN SYNTHESIS (TRANSLATION)

At the ribosome, the messenger RNA controls the binding of specific transfer RNA molecules each of which is bonded with a specific amino acid. Each tRNA has a definite base sequence which binds only with the complementary sequence in messenger RNA. The sequence in which the tRNA molecules are attached on mRNA, i.e., the order in which the amino acids are formed in the polypeptide chain is dependent upon the sequence of bases along the mRNA chain.

The sequence of four separate nucleotides is used to put across the information for combining 20 dissimilar amino acids into peptide chains, each amino acid has to be represented by the combination of at least three nucleotides (triplet). This holds true because there are just 16 dissimilar doublets of four nucleotides (4^2), but there are 64 triplets (4^3). These 64 three-letter code words are called **Codons**. On the other hand, as there are just 20 amino acids, more than one condon can code for the same amino acid,

e.g., both CUU and CUC can call leucine. Proline is encoded by CCU, CCA, CCG, and CCC. Therefore, codons can be synonyms and genetic code is degenerate. A difference of a single base in the DNA molecule or a single error in the reading of the code can cause a change in the amino acid sequence leading to **mutation**. A diagrammatic presentation of the mechanism or protein synthesis is given in Fig. 9.11.

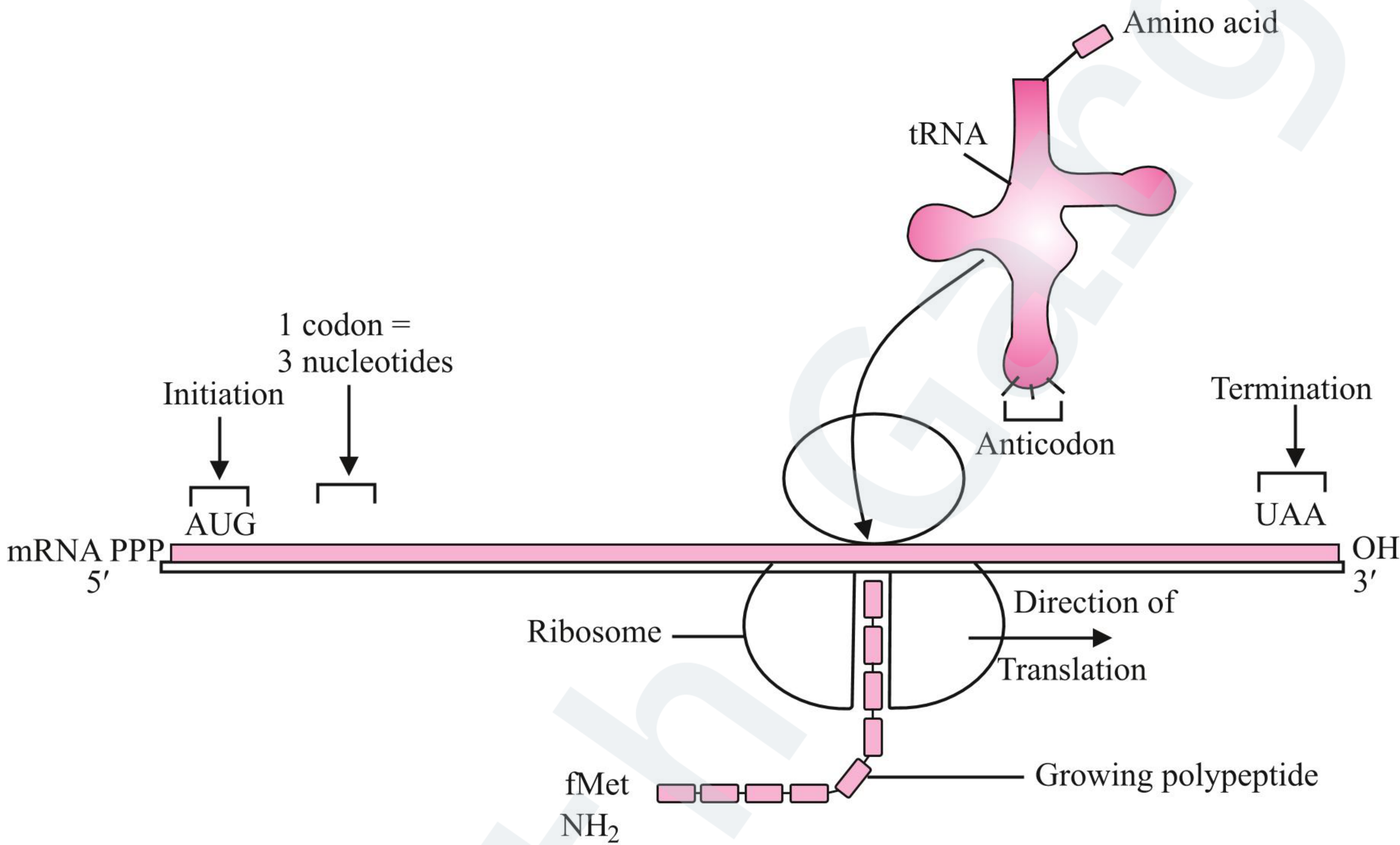


Fig. 9.11. Diagrammatic representation of protein synthesis

It is noteworthy that every tRNA molecule possesses an amino acid attachment site and a site that has three complementary nucleotides for recognising the triplets in mRNA (anticodon).

The relation between the nucleotide triplets and the amino acids is called the GENETIC CODE.

Types of RNA:

i. **Ribosomal-RNA (r-RNA):** This forms the site for protein

synthesis and helps the binding of m-RNA to the ribosomes during protein synthesis.

ii. **Messenger-RNA (m-RNA):** It carries the genetic information from DNA to the ribosomes where protein is being synthesised.

iii. **Transfer-RNA (t-RNA):** It acts as a carrier of amino acids, that is, it carries amino acids from different parts of the cytoplasm to the ribosomes, during protein synthesis.

Table 9.3 Structural and functional difference between DNA and RNA

Deoxyribonucleic Acid (DNA)	Ribonucleic Acid (RNA)
1. The sugar present in DNA is 2-deoxy D (–) ribose.	1. The sugar present in RNA is D (–)-ribose.
2. DNA contains cytosine and thymine as pyrimidine bases, and guanine and adenine as purine bases.	2. RNA contains cytosine and uracil as pyrimidine bases, and gaunine and adenine as purine bases.
3. DNA has a double stranded α -helix structure.	3. RNA has a single stranded α -helix structure.
4. DNA chiefly occurs in the nucleus of the cell.	4. RNA mainly occurs in the cytoplasm of the cell.
5. DNA molecules are very large; their molecular weight may vary from 6 million to 16 million.	5. RNA molecules are much smaller with molecular weights ranging from 20,000 to 40,0000.
6. DNA has the unique property of replication.	6. RNA usually does not replicate.
7. DNA controls the hereditary effects.	7. RNA controls the synthesis of proteins.

ILLUSTRATION 9.17

One strand of a DNA has the sequence ATGCTTCA. What is the sequence of the bases in the complementary strand?

Sol. We know that in DNA molecule, adenine (A) always pairs with thymine (T) and cytosine (C) always pairs with guanine (G). Thus,

sequence of bases in one strand:

A T G C T T C A

∴ sequence of bases in the complementary strand:

T A C G A A G T

Thus, the sequence of bases in the complementary strand is TACGAAGT.

ILLUSTRATION 9.18

What will be the sequence of bases on mRNA molecule synthesised on the DNA strand, TATCTACCTGGA?

Sol. We know that both in DNA and RNA, cytosine (C) pairs with guanine (G). Further, as RNA molecule does not contain thymine (T) but instead contains uracil (U), therefore, thymine (T) in DNA pairs with adenine (A) in RNA. However, adenine (A) in DNA must pair with uracil (U) in RNA. Thus,

Sequence of bases in one strand:

T A T C T A C C T G G A

∴ Sequence of bases in the complementary strand:

A U A G A U G G A C C U

Thus, the sequence of bases on the mRNA strand is:

AUAGAUGGACCU

9.5.5 Gene

Each segment of a DNA molecule that codes for a definite protein polypeptide is known as a **gene**. Thus, every protein in a cell possesses a corresponding gene. Genetic code is the relation between the nucleotide triplets and the amino acids.

Mutations

A mutation is defined as the chemical change in the succession of nitrogenous bases along the DNA strands which might lead to the synthesis of proteins with altered amino acid sequence. Such changes may either take place spontaneously, or might be caused by the exposure to X-ray or ultraviolet radiation, chemical agents, or viruses. Majority of the changes in DNA molecules get automatically repaired by the special enzymes available in the cells. Nevertheless, when the changes cannot be repaired by enzymes, mutations take place. Mutation results in proteins having altered amino acid sequences not having any biological activity leading to the death of the cell. In other words, mutation may result in defective genes that may cause genital disorders or diseases.

9.5.6 DNA FINGERPRINTING

It is known that every individual has unique fingerprints. These occur at the tips of the fingers and have been used for identification

for a long time but these can be altered by surgery. A sequence of bases on DNA is also unique for a person and information regarding this is called DNA fingerprinting. It is same for every cell and cannot be altered by any known treatment. DNA fingerprinting is now used.

- in forensic laboratories for identification of criminals.
- to determine paternity of an individual.
- to identify the dead bodies in any accident by comparing the DNA's of parents or children.
- to identify racial groups to rewrite biological evolution.

9.5.7 BIOLOGICAL FUNCTIONS OF NUCLEIC ACIDS

DNA is the chemical basis of heredity and may be regarded as the reserve of genetic information. DNA is exclusively responsible for maintaining the identity of different species of organisms over millions of years. A DNA molecule is capable of self duplication during cell division and identical DNA strands are transferred to daughter cells. Another important function of nucleic acids is the protein synthesis in the cell. Actually, the proteins are synthesised by various RNA molecules in the cell but the message for the synthesis of a particular protein is present in DNA.

9.6 VITAMINS

Vitamins are the indispensable dietary factors required by an organism in minute quantities. Their absence results in specific deficiency diseases. Vitamins are crucial for life and a balanced supply is needed in food because the organism cannot synthesise these compounds. Plants can synthesise all vitamins but **just a few are synthesised in animals**. Vitamin D can be provided through food or can be produced in the skin through the irradiation of sterols with sunlight (ultraviolet light). Human body is capable of synthesising vitamin A from carotene while some members of **vitamins B complex** and **vitamin K** get synthesised by microorganisms available in the intestinal tract.

Vitamins are extensively dispersed in nature both in plants and animals. All cells in the body have the capacity to store vitamins to some extent or the other. Nevertheless, majority of vitamins have been synthesised and are available for commercial purposes. These are really effective on oral intake. Vitamins possess wide-ranging chemical structures.

These are designated by alphabets A, B, C, D, E, etc., in the order of their discovery. Further, any subgroup of an individual vitamins is designated by the number subscript, e.g., A₁, A₂, B₁, B₂, B₆, B₁₂, D₁, D₂, etc.

9.6.1 CLASSIFICATION OF VITAMINS

Based on their solubility, vitamins are usually classified into two broad types: fat soluble and water soluble. These two groups perform different functions.

Fat-soluble vitamins: These are oily substances that are not readily soluble in water. The group comprises vitamins A, D, E, and K. Liver cells are rich in fat soluble vitamins, e.g., Vitamin A and Vitamin D. This group of hydrophobic, lipid soluble vitamins as a class is not absorbed in the body unless fat absorption

and digestion proceed normally. Their deficiency can result in malabsorptive disease. Also, excess intake of these vitamins might cause hypervitaminoses.

Water-soluble vitamins: This group comprises the remaining vitamins, e.g., vitamins of B group (B-Complex), vitamin C, etc. The water-soluble vitamins are stored to a much lesser extent in the cells. Vitamin H (Biotin) is an exception because it is neither soluble in water nor in fat.

9.6.2 PHYSIOLOGICAL FUNCTIONS OF VITAMINS

Vitamins catalyse biological reactions in very low concentration; therefore, the daily necessity of any vitamin for any individual is very small. Nevertheless, there is not a fixed daily dose of any

vitamin for an individual and differs according to the size, age, and rate of metabolism of that person. Young people require higher quantity of vitamins in comparison to elders. Also, the requirement goes up when a person performs exercise. Growing children and pregnant mothers require more vitamins. The intestinal organisms may synthesise vitamins in considerable amounts and thus play a vital role in maintaining the quantity of vitamins available to the organism. Majority of the vitamins of B-complex group and vitamin K are the vitamins synthesised by the intestinal organisms. These may be absorbed in varying amounts and utilised.

A lack of one or more vitamins results in characteristic deficiency symptoms in humans. Multiple deficiencies resulting from the lack of more than one vitamin are usually common in human beings. This state of vitamin deficiency is called **avitaminoses**.

Table 9.4 Vitamin sources and the diseases caused by lack of vitamins

Some Important Vitamins (Characteristics, Sources and Deficiency Diseases)

Vitamin	Characteristics	Source	Deficiency diseases
1. Vitamin A or Retinol:	Soluble in oil and fats but insoluble in water, stable to heat. Promotes growth and vision. It also increases resistance to disease.	Milk, butter, egg, fish and fish oil (cod liver oil). It can also be synthesised in the body from carotenoids present in carrots, tomatoes, ripe mangoes etc. Carotenoids are the precursors of vitamin A.	Night blindness, stunted growth, xerosis (drying of skin), xerophthalmia (cornea becomes opaque).
2. Vitamin B complex:	Soluble in water but insoluble in oils and fats. Destroyed by heat above 310 K.	Pulses, nuts, whole cereals (rice, wheat etc.), rice bran, yeast, egg yolk, milk, green vegetables and fruits.	Beriberi (paralysis of legs and general weakness) and corners of the mouth.
a. Vitamin B ₁ or Thiamine.			
b. Vitamin B ₂ or Riboflavin.	Soluble in water but insoluble in oils and fats. Sensitive to light but stable to heat. Essential for growth and general health.	Milk, yeast, green vegetables, meat, liver, kidney etc.	Causes pellagra (shrivelled skin) and anaemia (bloodlessness) in man Effects central nervous system. Causes general weakness, insomnia and irritability.
c. Vitamin B ₃ or Nicotinamide or Niacin		Meat, Milk, Nut, Sugarcane etc.	Whitening of hair, mentally retardness
d. Vitamin B ₅ or Pantothenic acid		Meat, Ground Potato, Tomato, Nut, Leafy Vegetables etc.	Pellagra or 4-D syndrome
e. Vitamin B ₆ (It is a mixture of three substances-pyridoxine, pyridoxal and pyridoxamine).	Soluble in water but insoluble in oils and fats.	Rice bran, yeast, meat, fish, eggs, whole cereals (wheat, maize, rice etc.)	Pernicious anaemia, inflammation of tongue and mouth.
f. Vitamin B ₇ or Biotin		Meat, Egg, Liver, Milk, etc.	Paralysis, Body pain, Hair Falling
g. Vitamin B ₁₂ or cyanocobalamin contains cobalt	Water soluble, stable to heat.	Milk, egg and all animal tissues.	Anaemia, Jaundice, Pernicious Glutemic.
3. Vitamin C or Ascorbic acid.	Soluble in water but insoluble in oils and fats. Destroyed by cooking or prolonged exposure to air. It increases resistance of the body towards diseases. Maintains healthy skin in and helps in the healing of cuts and abrasions.	Citrus fruits (oranges, lemon grape fruit, lime etc.), amla, cabbage, guava etc.	Causes scurvy (bleeding of gums), pyorrhea (loosening of teeth and bleeding of gums).

4. Vitamin D or ergocalciferol (a mixture of vitamins D ₂ and D ₃)	Soluble in oil and fats but insoluble in water. Stable to heat and resistant to oxidation. It controls absorption of calcium and phosphorus from intestine. Vitamin D is structurally related to steroids.	Eggs, fish liver oils, butter, liver, meat etc. Vitamin D ₂ is produced by plants from ergosterol when exposed to light. Vitamin D ₃ is produced in skin on exposure to light.	Rickets (bending of bones) in children and deformation of bones and teeth. Osteomalacia in adults.
5. Vitamin E (It is a mixture of four vitamins called α , β , γ , and δ -tocopherols).	Soluble in oils and fats but insoluble in water. Stable to heat, light and oxidation.	Eggs, milk, fish, wheat gram oil nuts, cotton seed oil, peanut oil etc.	Needed for beautiful glowing skin. Antioxidant, prevents destruction of RBC. In animals, its deficiency causes sterility in males, death of embryos and muscle degeneration.
6. Vitamin K or phyloquinone (A mixture of two vitamins called K ₁ and K ₂)	Soluble in oils and fats but insoluble in water. Sensitive to light and alkali.	Vitamin K ₁ can be obtained from green leafy vegetables like cabbage, spinach, carrot tops and alfalfa. Vitamin K ₂ occurs mainly in intestinal bacteria.	Its deficiency leads to faulty blood clotting and haemorrhage. It restores normal blood clotting.
7. Coenzyme Q₁₀		Chloroplasts of green plants and mitochondria of animals.	Low order of immunity of body against many diseases.

CONCEPT APPLICATION EXERCISE 9.3

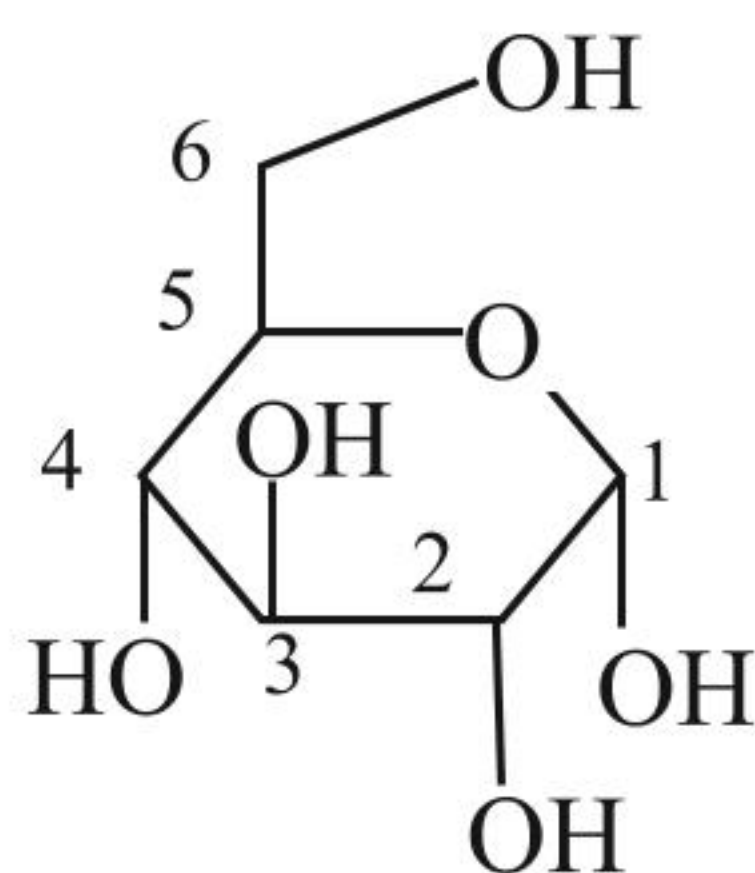
- Define the terms:
 - Gene
 - Genetic code
 - Transcription
 - Translation
 - Codons
- List three functions of nucleotides in a cell.
- 'The two strands of DNA are not identical, but are complementary'. Explain this statement.
- Write two functions of carbohydrates in plants.
- What type of bonding occurs in globular protein?
- What will be the sequence of bases on mRNA molecules synthesised on the following strand of DNA?
T A T C T A C C T G G A
- Name one reducing and one non-reducing disaccharide.
- Name one fibrous and one globular protein.
- What causes sickle cell anaemia?
- Give one example of a denatured protein.
- Name a polypeptide hormone which maintains the glucose level in the blood.
- What is nucleoside?
- What is nucleotide?
- Which purine and pyrimidine bases are present in DNA and RNA?
- What is mutarotation?
- What are neutral amino acids? Give two examples.
- What are acidic amino acids?
- What are basic amino acids? Give one example.
- Name the enzymes that help in the digestion of carbohydrates.
- What is deficiency disease of proteins in our body?
- Arrange the following sugars in the increasing order of sweetness: glucose, fructose, sucrose.
- Which enzyme dissolves blood clots in the coronary artery?
- Name three nucleic acids which are used in protein synthesis.
- What are biofuels?
- What are the monomers constituting proteins?
- What is enzyme specificity?
- What is the effect of pH on the action of enzyme?
- Explain the functions of nucleic acids.

Exercises

Single Correct Answer Type

Preparation and Properties of Monosaccharides

- Fructose reduces Fehling's solution due to the presence of:
 - Hydroxy group
 - Aldehyde group
 - Ketone group
 - α -Hydroxy ketone group
- Osazone formation involves only 2-carbon atoms of glucose because of:
 - Oxidation
 - Reduction
 - Chelation
 - Hydrolysis
- In the ring structure of fructose, the anomeric carbon is:
 - C—1
 - C—5
 - C—2
 - C—6
- A pair of diastereomers that differ only in the configuration about a single carbon atom are called:
 - Anomers
 - Epimers
 - Conformers
 - Enantiomers
- In α -D-Glucose, the anomeric carbon is at:



- 1
 - 2
 - 3
 - 4
- Carbohydrates which differ in configuration at the glycosidic carbon (*i.e.*, C₁ in aldoses and C₂ in ketoses) are called:
 - Anomers
 - Epimers
 - Diastereomers
 - Enantiomers
 - Invert sugar is an equimolar mixture of:
 - D-Glucose and D-Fructose
 - D-Glucose and L-Fructose
 - D-Glucose and L-Glucose
 - D-Fructose and L-Fructose
 - Number of possible isomers of glucose is:
 - 16
 - 14
 - 10
 - 8
 - The number of chiral centers in the open chain structure of glucose is:
 - 3
 - 4
 - 5
 - 6
 - Glucose $\xrightarrow{\text{Br}_2 + \text{H}_2\text{O}}$ Product; Product is:
 - Glucaric acid
 - Gluconic acid
 - Hexanoic acid
 - Bromo hexane
 - Carbohydrate that on attempt hydrolysis are not cleaved to smaller carbohydrates are called:

- Monosaccharide
- Oligosaccharide
- Polysaccharide
- Disaccharide

12. Glucose $\xrightarrow{\text{HCN}}$ $\xrightarrow{\text{Hydrolysis}}$ $\xrightarrow{\text{HI heat}}$ A, A is:

- glucaric acid
- 2-Iodoheptane
- heptane
- Heptanol

13. Carbohydrates are commonly defined as:

- Polycarbonyl compounds
- Polycarboxylic acid
- Polyhydroxy carboxylic acid
- Polyhydroxy aldehyde and ketone

14. Ring structure of glucose is due to formation of hemiacetal and ring formation of hemiacetal and ring formation between:

- C₁ and C₅
- C₁ and C₄
- C₁ and C₃
- C₂ and C₄

15. The minimum number of carbon atoms that should be present in a carbohydrate is:

- 2
- 3
- 4
- 6

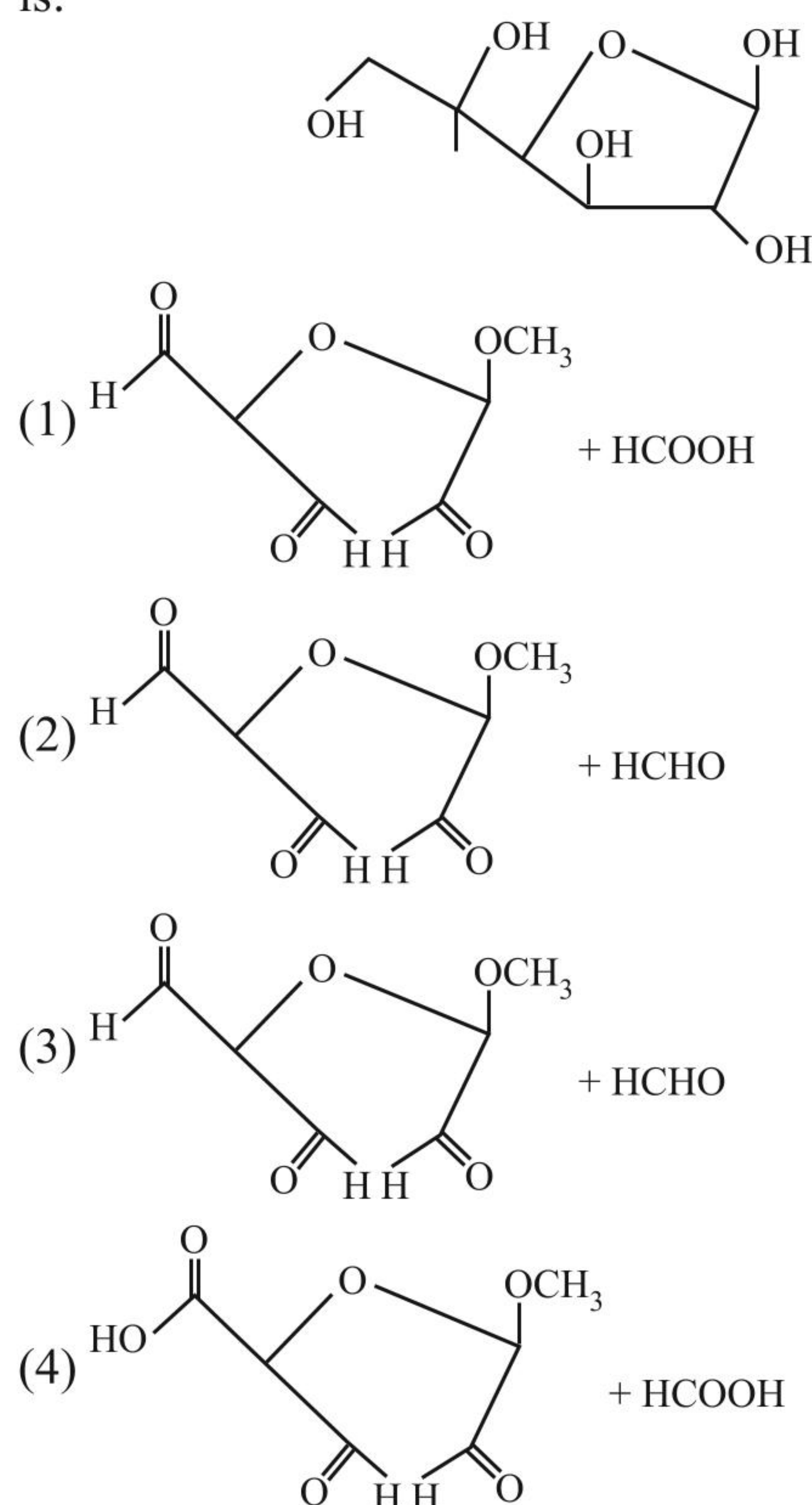
16. Which of the following monosaccharides is a pentose?

- Glucose
- Fructose
- Ribose
- Galactose

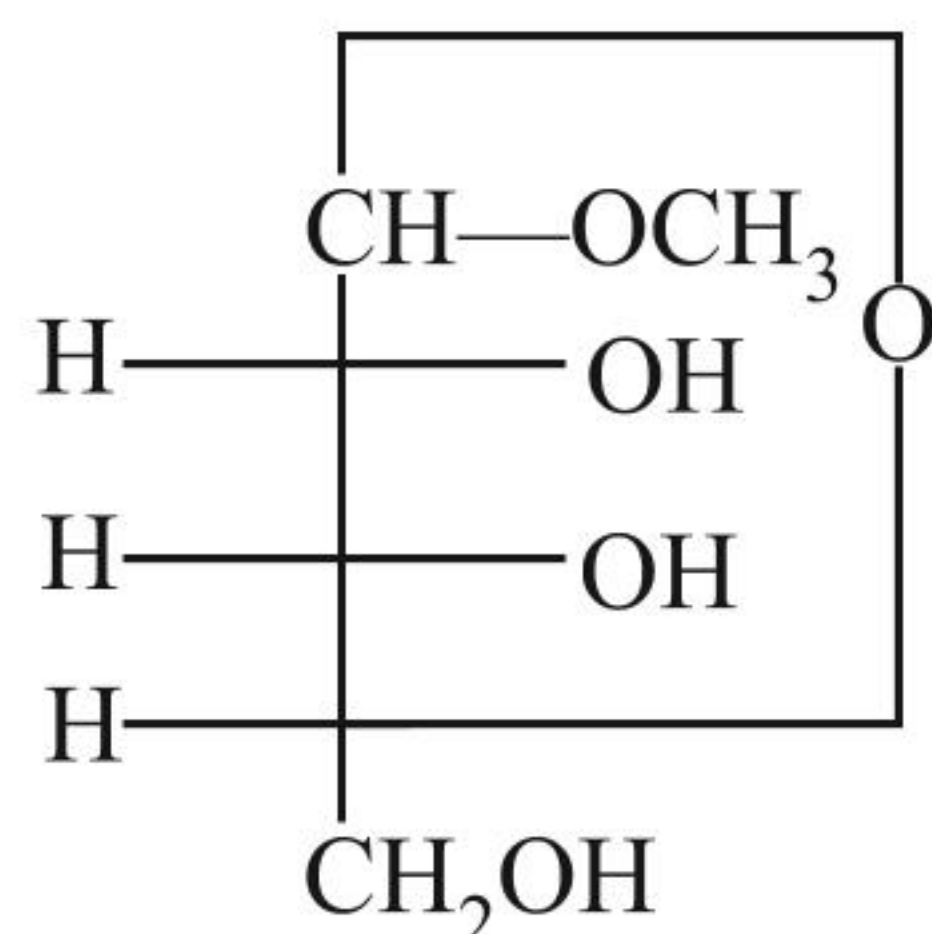
17. Which one of the following is used to identify glucose?

- Neutral FeCl₃
- CHCl₃ + KOH (alc.)
- C₂H₅ONa
- Ammoniacal AgNO₃

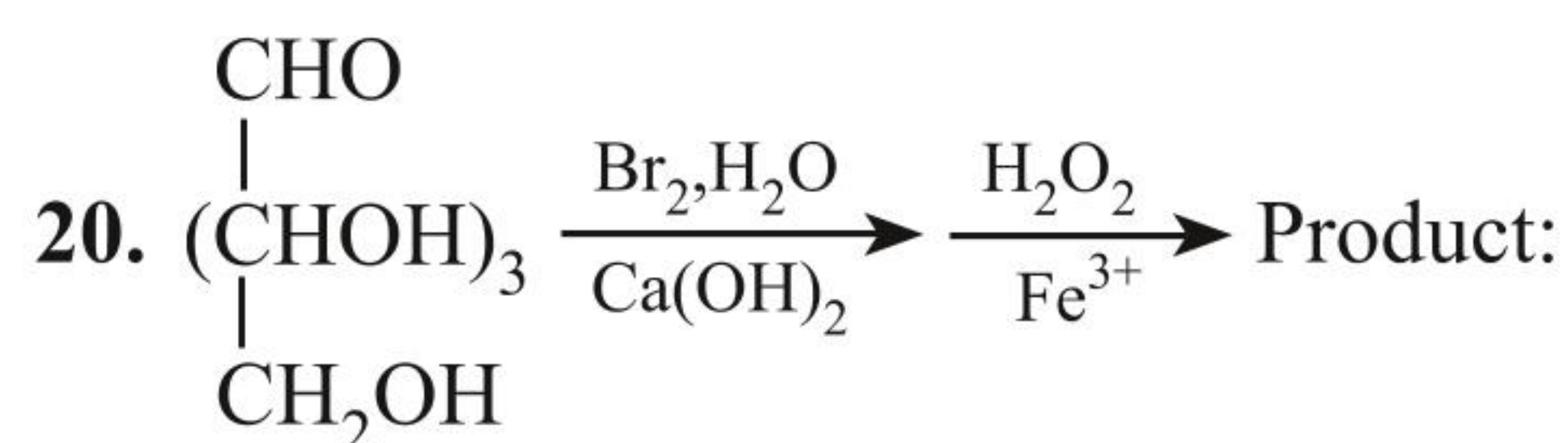
18. The products of HIO₄ oxidation of the following compound is:



19. How many moles of HIO_4 is required to break down the given molecule here ?



- (1) 0 (2) 1
(3) 2 (4) 3



- (1) $\begin{array}{c} \text{COOH} \\ | \\ (\text{CHOH})_3 \\ | \\ \text{CH}_2\text{OH} \end{array}$ (2) $\begin{array}{c} \text{COOH} \\ | \\ (\text{CHOH})_4 \\ | \\ \text{CH}_2\text{OH} \end{array}$
(3) $\begin{array}{c} \text{CHO} \\ | \\ (\text{CHOH})_2 \\ | \\ \text{CH}_2\text{OH} \end{array}$ (4) $\begin{array}{c} \text{COOH} \\ | \\ (\text{CHOH})_3 \\ | \\ \text{COOH} \end{array}$

21. The change in optical rotation with time of freshly Prepared solution of sugar is known is :

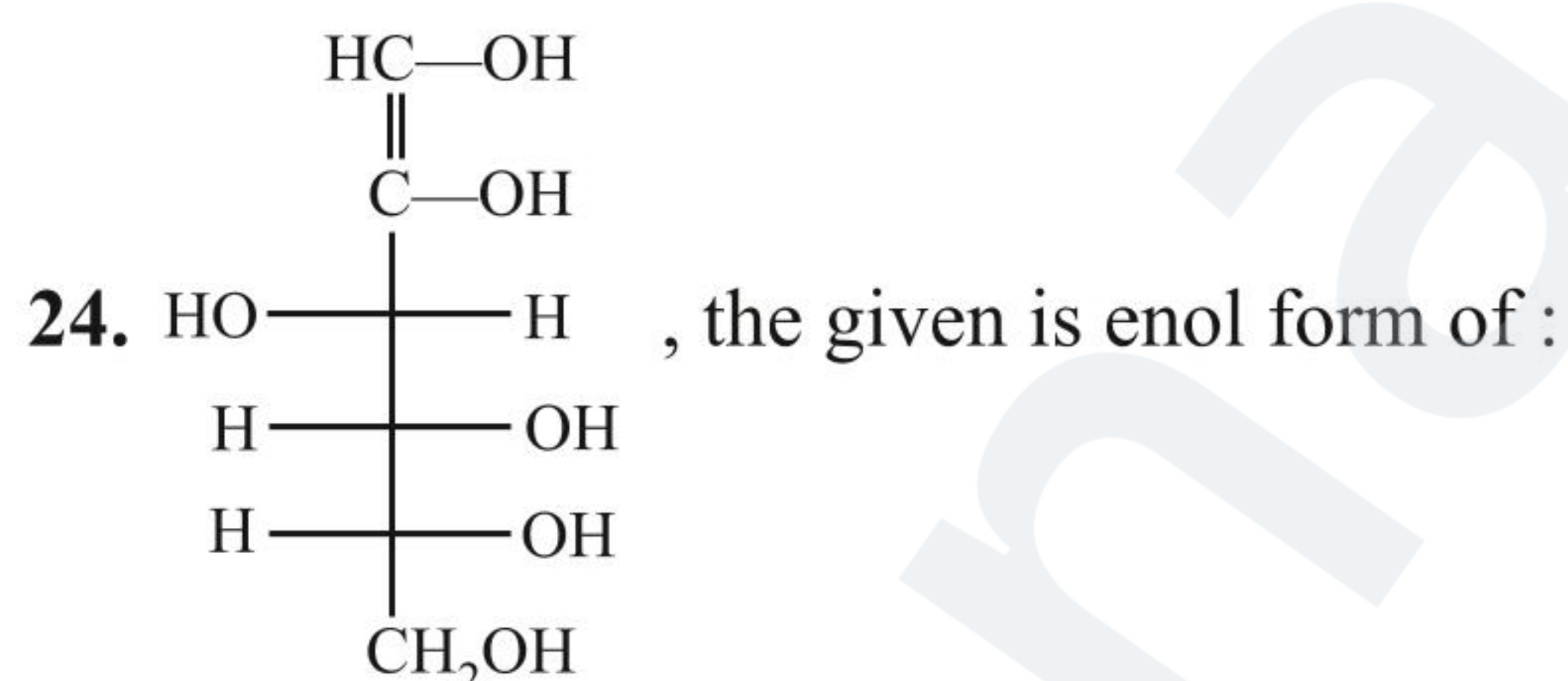
- (1) Specific rotation (2) Mutarotation
(3) Inversion (4) Rotatory motion

22. The numbers of chiral centers present in glucopyranose and fructofuranose are:

- (1) 4 and 3 (2) 5 and 4
(3) 4 in each (4) 5 in each

23. An aldose is converted into its next higher homologue by:

- (1) Ruff's method (2) Amadori rearrangement
(3) Killiani synthesis (4) Wohl's method

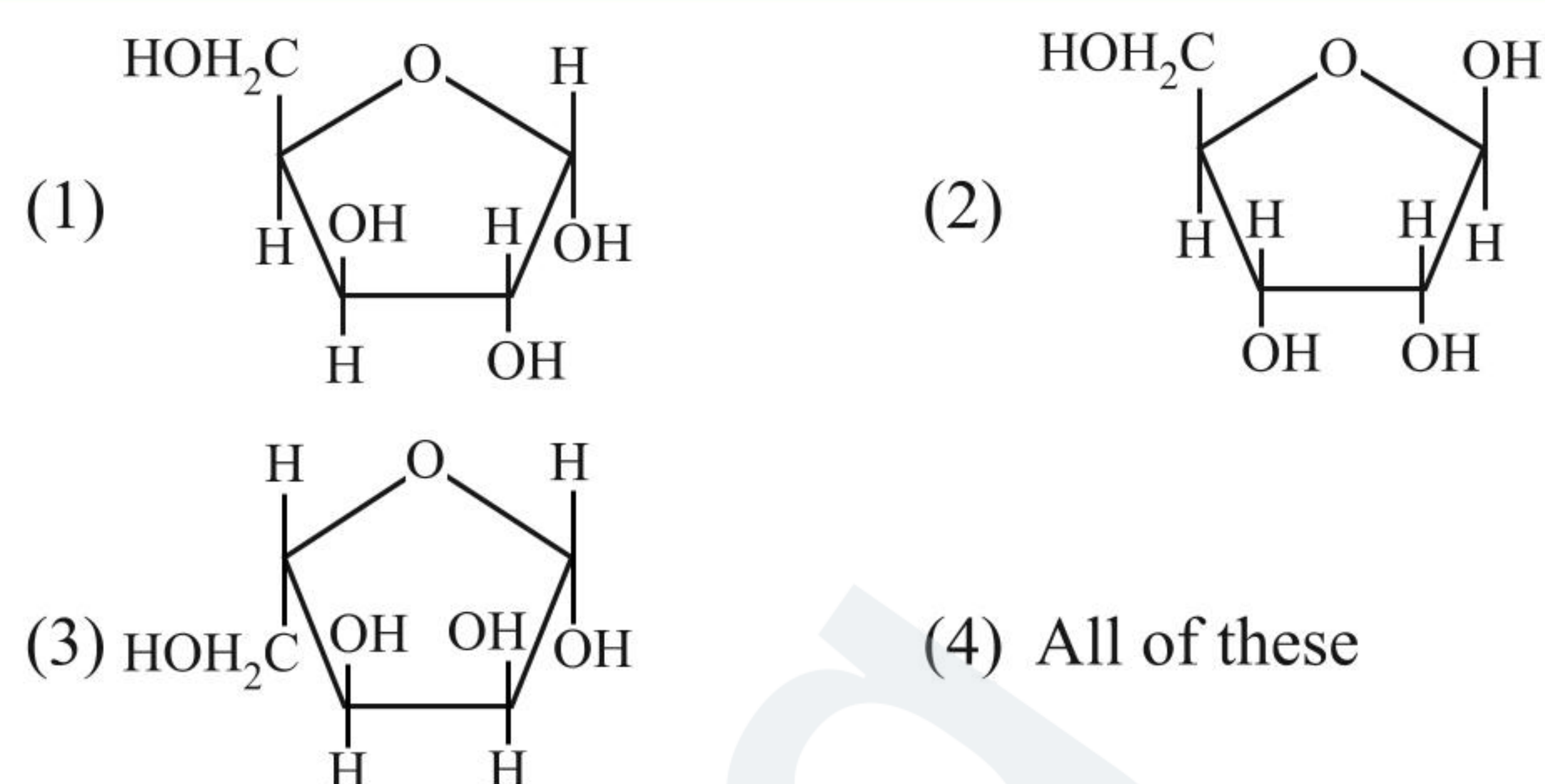
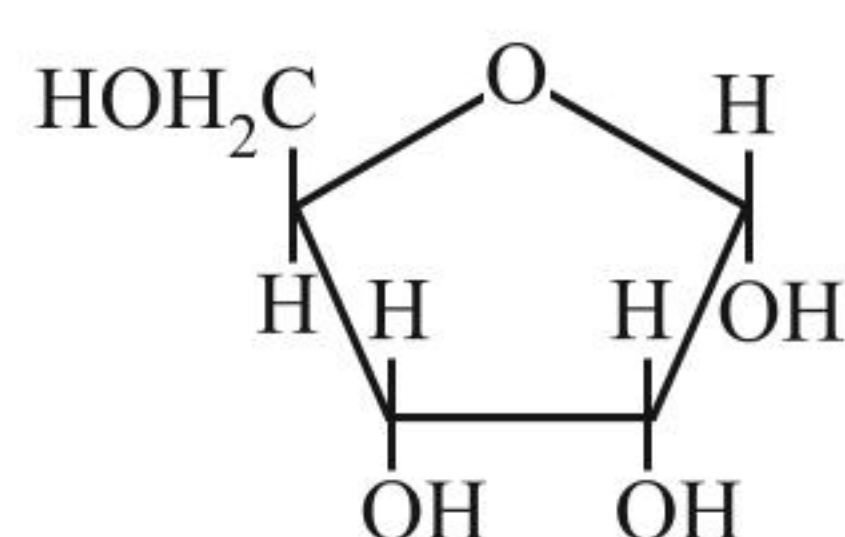


- (1) D-Glucose (2) D-Mannose
(3) D-Fructose (4) All of these

25. Periodic acid splits glucose and fructose into formic acid and formaldehyde. Ratio of formic acid and formaldehyde from glucose and fructose is:

- (1) 5/1 and 4/2 (2) 5/1 and 3/2
(3) 4/2 and 4/2 (4) 3/2 and 4/2

26. Which of the following represents the anomer of compound shown?



27. Glucose and Fructose can be differentiated by:

- (1) $\text{Br}_2/\text{H}_2\text{O}$ (2) Cold KMnO_4
(3) $\text{Br}_2/\text{H}_2\text{O}$ (4) PCC

28. Which of the following reagents may be used to identify glucose?

- (1) Neutral FeCl_3 Solution (2) Ammoniacal AgNO_3
(3) CHCl_3 and KOH (alc.) (4) NaHSO_3

29. Pyranose ring consist of a skelton of:

- (1) 5 carbon atoms and one oxygen atom
(2) 6 carbon atoms
(3) 6 carbon atoms and one oxygen atom
(4) 4 carbon atoms and one oxygen atom

30. Glucose and galactose differ in configuration at:

- (1) C—1 (2) C—2
(3) C—3 (4) C—4

31. Glycosidic linkage is:

- (1) An amide linkage (2) An ester linkage
(3) An ether linkage (4) An amine linkage

32. Glucose when treated with CH_3OH in presence of dry HCl gives α - and β -methylglucosides because it contains:

- (1) an aldehydic group (2) $-\text{CH}_2-\text{OH}$ group
(3) Five $-\text{OH}$ group (4) None of these

33. Rapid interconversion of α -D-Glucose and β -D-Glucose in solution is known as:

- (1) Racemisation (2) Asymmetric induction
(3) Fluxional isomerisation (4) Mutarotation

34. Which of the following is a non reducing sugar?

- (1) Glyceraldehyde (2) Glucose
(3) Fructose (4) Sucrose

35. Which of the following is C—2 epimer of D-Glucose?

- (1) D-Galactose (2) L-Glucose
(3) D-Mannose (4) D-Fructose

36. Glucose does not react with:

- (1) $\text{C}_6\text{H}_5\text{NHNH}_2$ (2) $\text{H}_2\text{N}-\text{OH}$
(3) HCN (4) NaHSO_3

37. C_3 -epimer of D-Glucose is:

- (1) D-Glucose (2) D-Allose
(3) D-Altrose (4) D-Mannose

38. C_2 -epimer of D-Glucose is:

- (1) D-Glucose (2) D-Allose
(3) D-Altrose (4) D-Mannose

39. Reduction of hexose *A* (molecular formula $C_6H_{12}O_6$) with sodium borohydride gives compounds *B* and *C*. Compound *B* is optically inactive, whereas compound *C* is optically active. Which of the following is compound *A*?

- (1) D-fructose (2) D-glucose
(3) D-mannose (4) D-galactose

40. Which of the following compounds does not undergo mutarotation?

- (1) glucose (2) sucrose
(3) ribose (4) fructose

41. D-Glucose exist in x different forms. The value of x (stereoisomer) is:

- (1) 3 (2) 2
(3) 4 (4) 5

42. D-glucose & D-fructose can be differentiated by:

- (1) Fehling solution (2) Tollens reagent
(3) Benedict test (4) Br_2/H_2O

43. Stereoisomers of aldohexose is (a) and stereoisomers of ketohexose is (b).

Ratio of a/b is:

- (1) 1/2 (2) 2/1
(3) 4/1 (4) 1/4

44. Which one of the following is non-reducing sugar?

- (1) Glucose (2) Arabinose
(3) Fructose (4) Sucrose

45. Which one of the following is reducing sugar?

- (1) Starch (2) Cellulose
(3) Glycogen (4) Fructose

46. Which of the following reagents *cannot* distinguish between glucose and fructose?

- (1) Tollen's reagent (2) Fehling's solution
(3) Benedict's solution (4) All of these

47. The number of chiral carbons in β -D (+)-glucose is:

- (1) 5 (2) 6
(3) 3 (4) 4

48. α - and β -Glucose differ in the orientation of the ($-OH$) group around:

- (1) C_1 (2) C_2
(3) C_3 (4) C_4
(5) C_5

49. Methyl- α -D-glucoside and methyl- β -D-glucoside are:

- (1) Epimers
(2) Anomers
(3) Enantiomers
(4) Conformational diastereomers

50. In addition to an aldehyde group, glucose contains:

- (1) One secondary and four primary OH groups.
(2) One primary and four secondary OH groups.
(3) Two primary OH and three secondary OH groups.
(4) Three primary OH and two secondary OH groups.

51. The term anomer of glucose refers to:

- (1) Isomers of glucose that differ in configuration at carbons one and four ($C-1$ and $C-4$).
(2) A mixture of D-glucose and L-glucose.
(3) Enantiomers of glucose.
(4) Isomers of glucose that differ in configuration at carbon one ($C-1$).

52. The Ruff degradation used to reduce the carbon chain in an

- (1) Alcohol (2) Alkene
(3) Ketose (4) Aldose

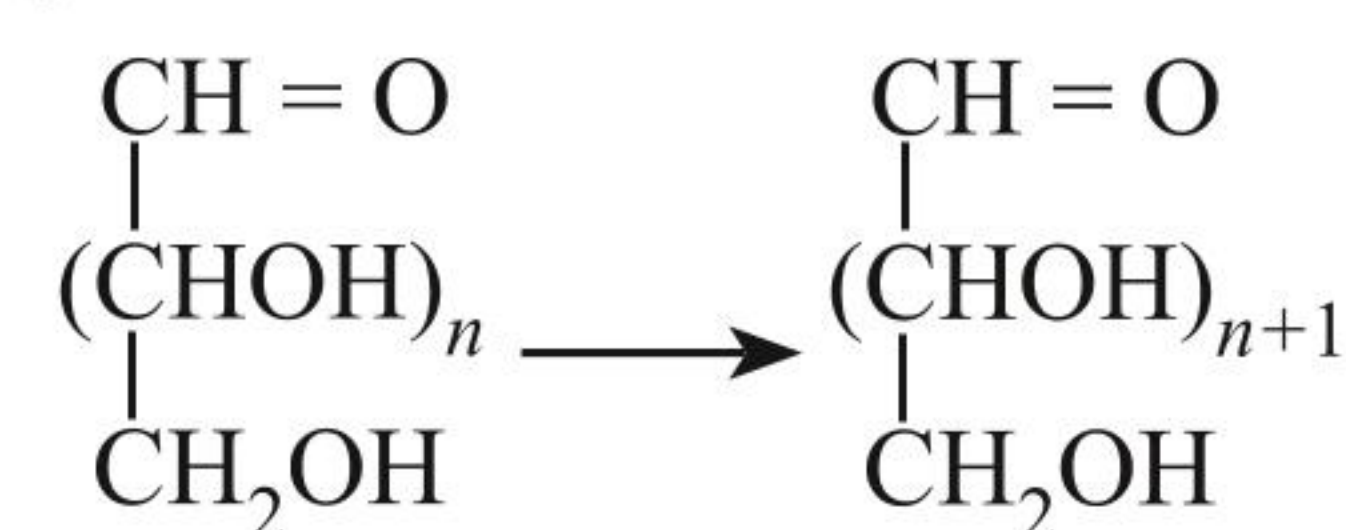
53. The Kiliani's synthesis is used to increase the carbon chain in:

- (1) Acid (2) Alcohol
(3) Aldose (4) Ketose

54. Which of the following statements is incorrect?

- (1) α -D-glucose and β -D-glucose are enantiomers.
(2) D-Glyceraldehyde and L-glyceraldehyde are epimers.
(3) The reserve carbohydrate of animals is glycogen.
(4) Few aldohexoses which react with phenylhydrazine to give identical osazones are epimers.

55. The following conversion can be carried out by using the reaction sequence:



(1) (i) Ag^+ , $NH_3/\bar{O}H$ (ii) H^+/Δ (iii) $Na-Hg$

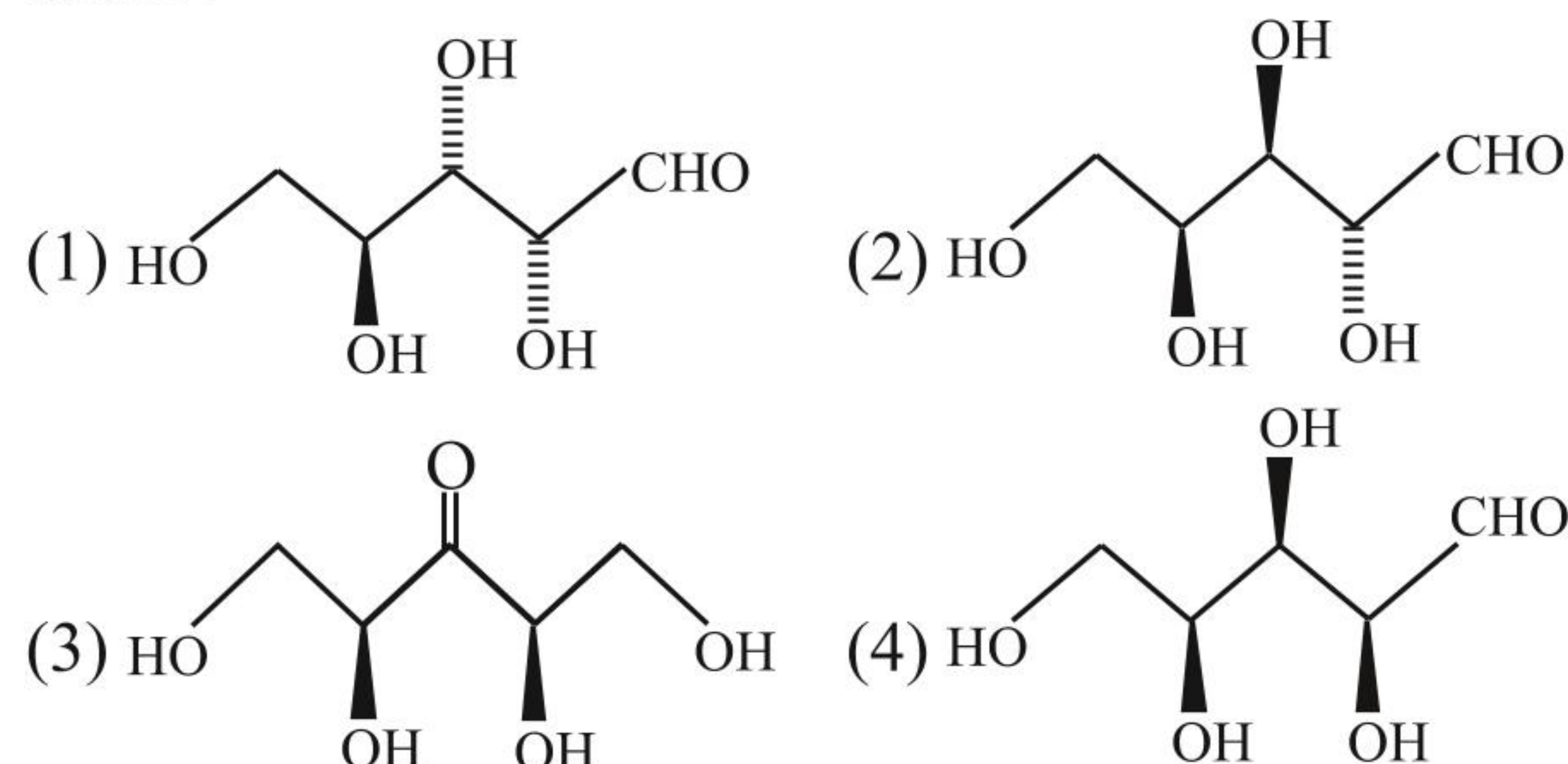
(2) (i) NH_2OH / Trace acid (ii) Ac_2O , $100^\circ C$

(iii) HO^+ , H_2O

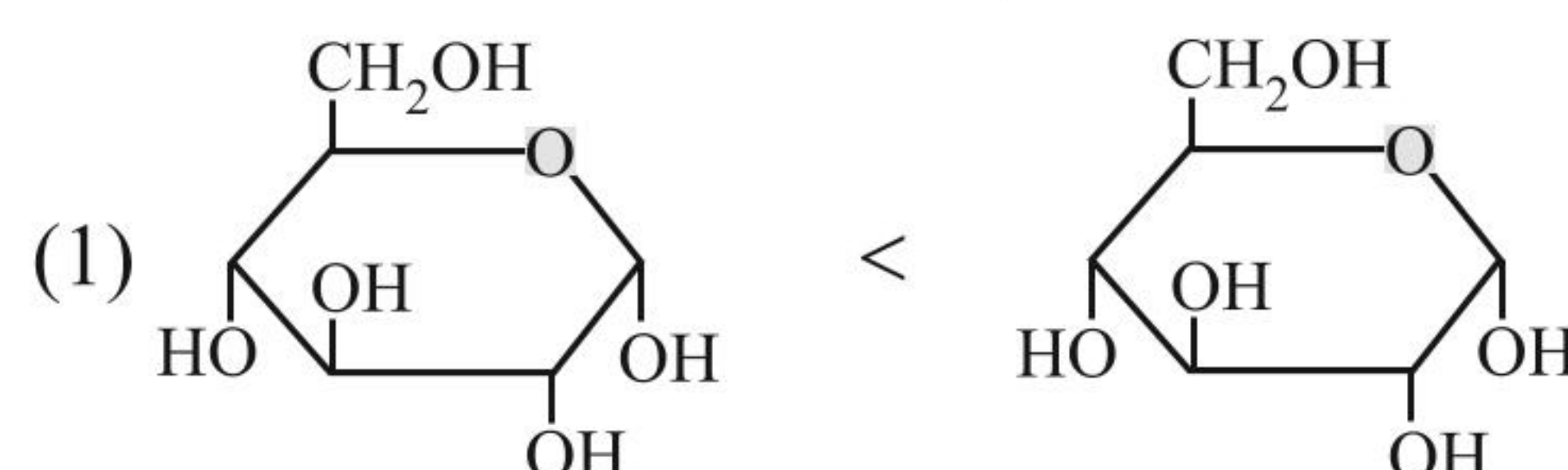
(3) (i) $CH_3 - \overset{\overset{O}{\parallel}}{C} - Cl$ (ii) Br_2/H_2O (iii) H_3O^+
Excess

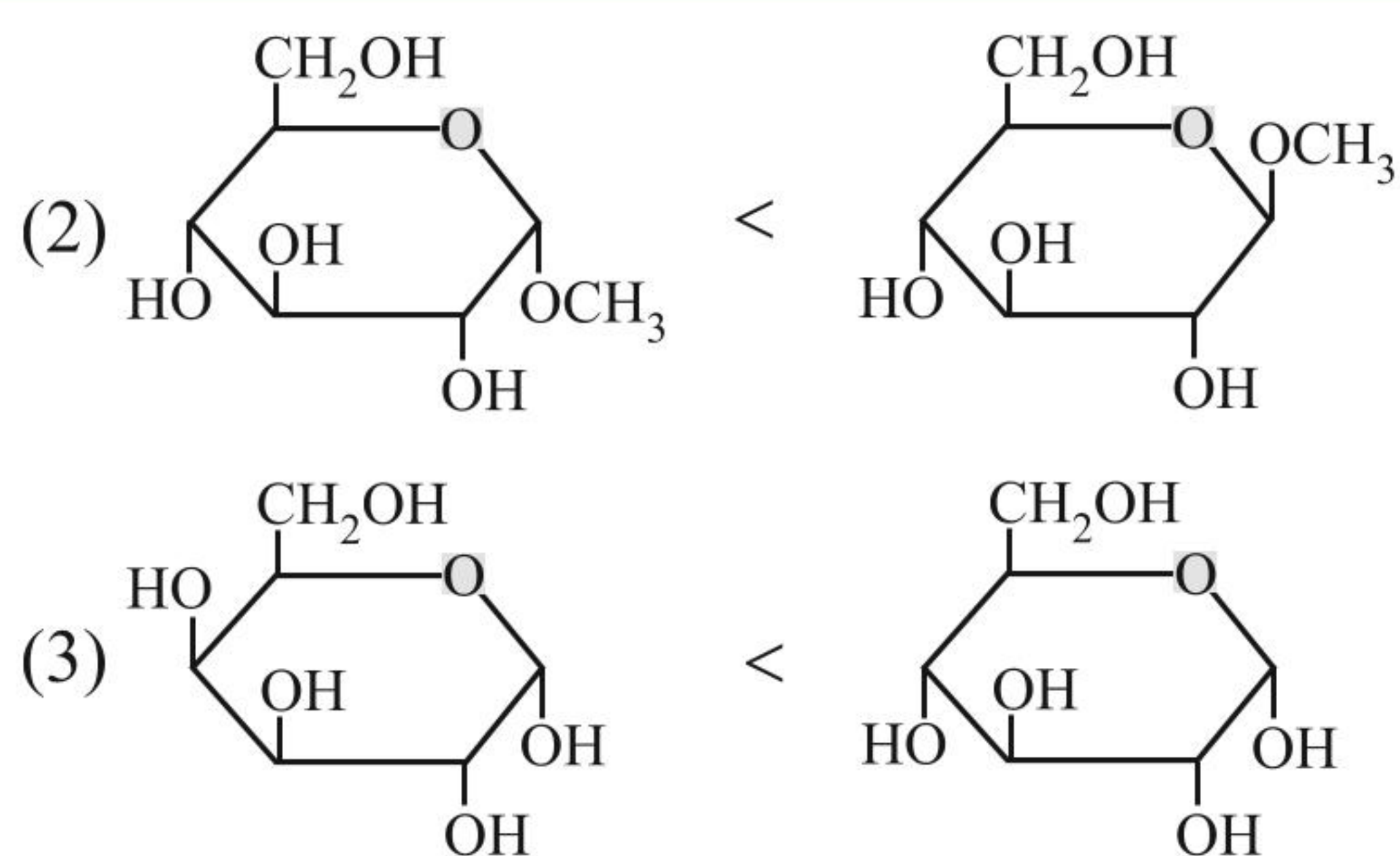
(4) (i) $NaCN/HCl$ (ii) $H_2/Pd/BaSO_4$ (iii) HCl/H_2O

56. Which of the following monosaccharide is not optically active?



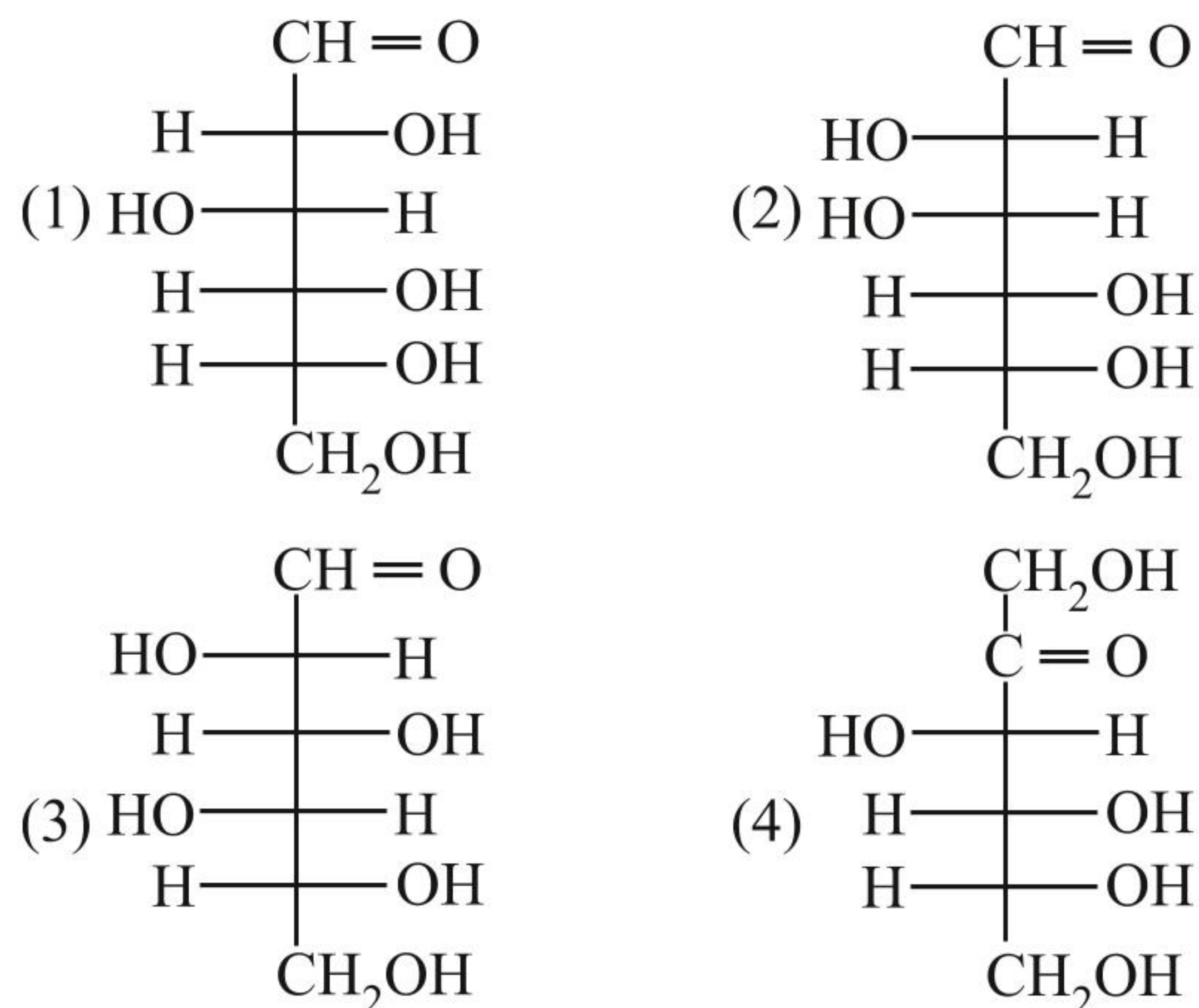
57. The correct order of stability is:





(4) All of these

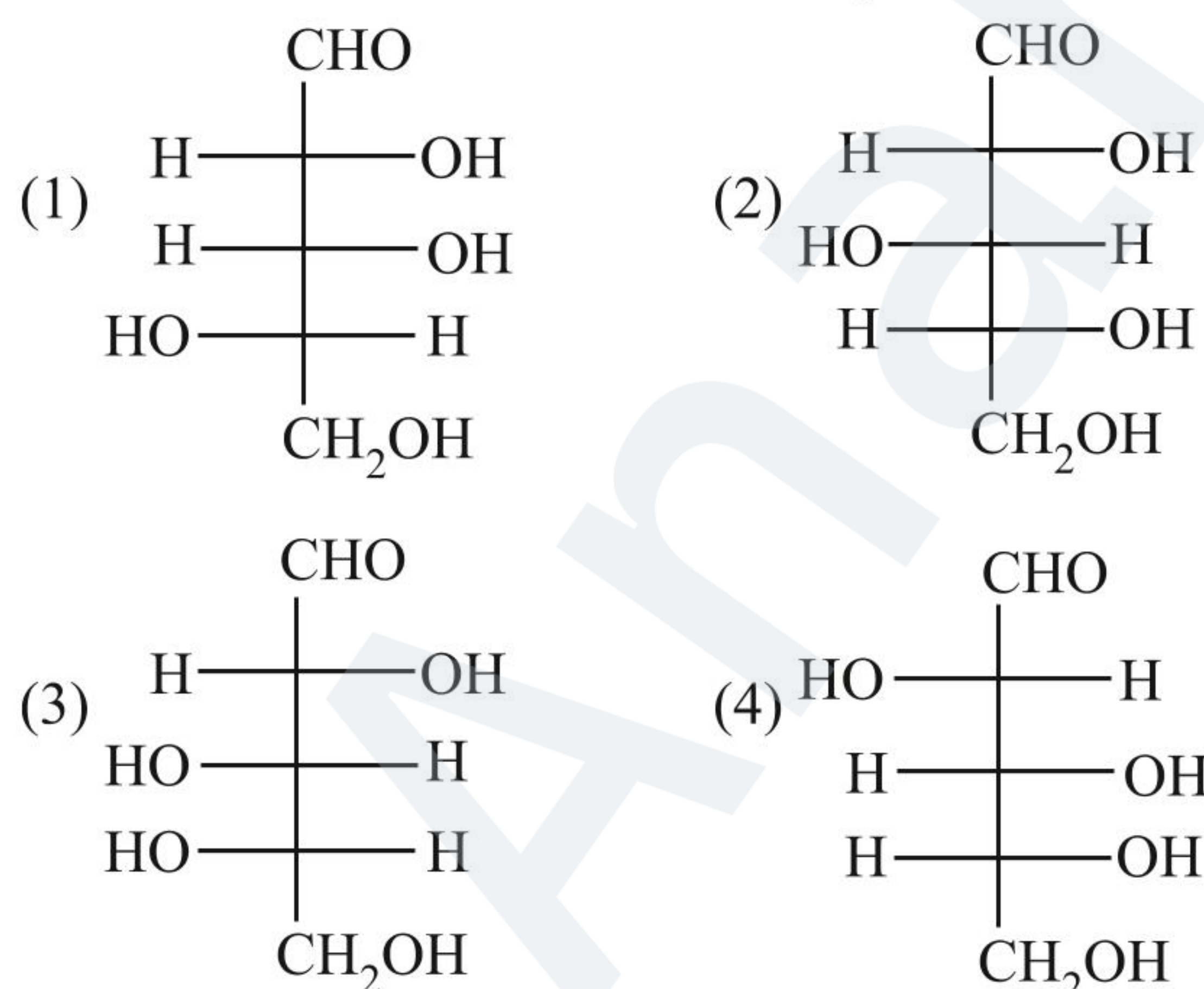
58. Which monosaccharides on reaction with Ph-NH-NH_2 gives osazone different from other?



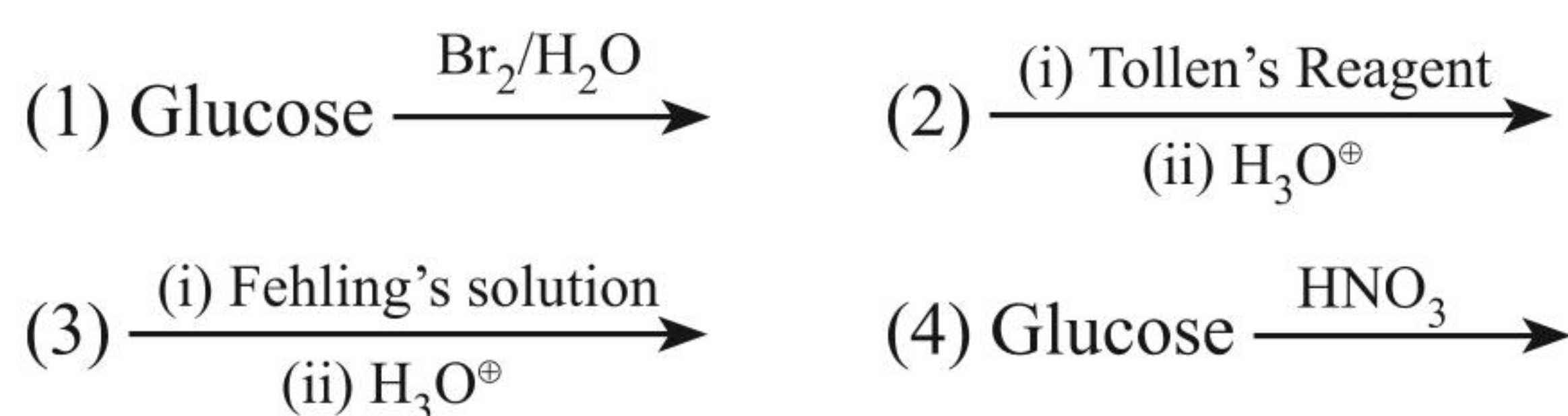
59. Formaldehyde is obtained as one of the product during reaction of HIO_4 and:

- (1) Methyl α -D-glucopyranoside
(2) Methyl α -D-glucofuranoside
(3) 2,3-Butandiol
(4) 1-Hydroxy-2-buanone

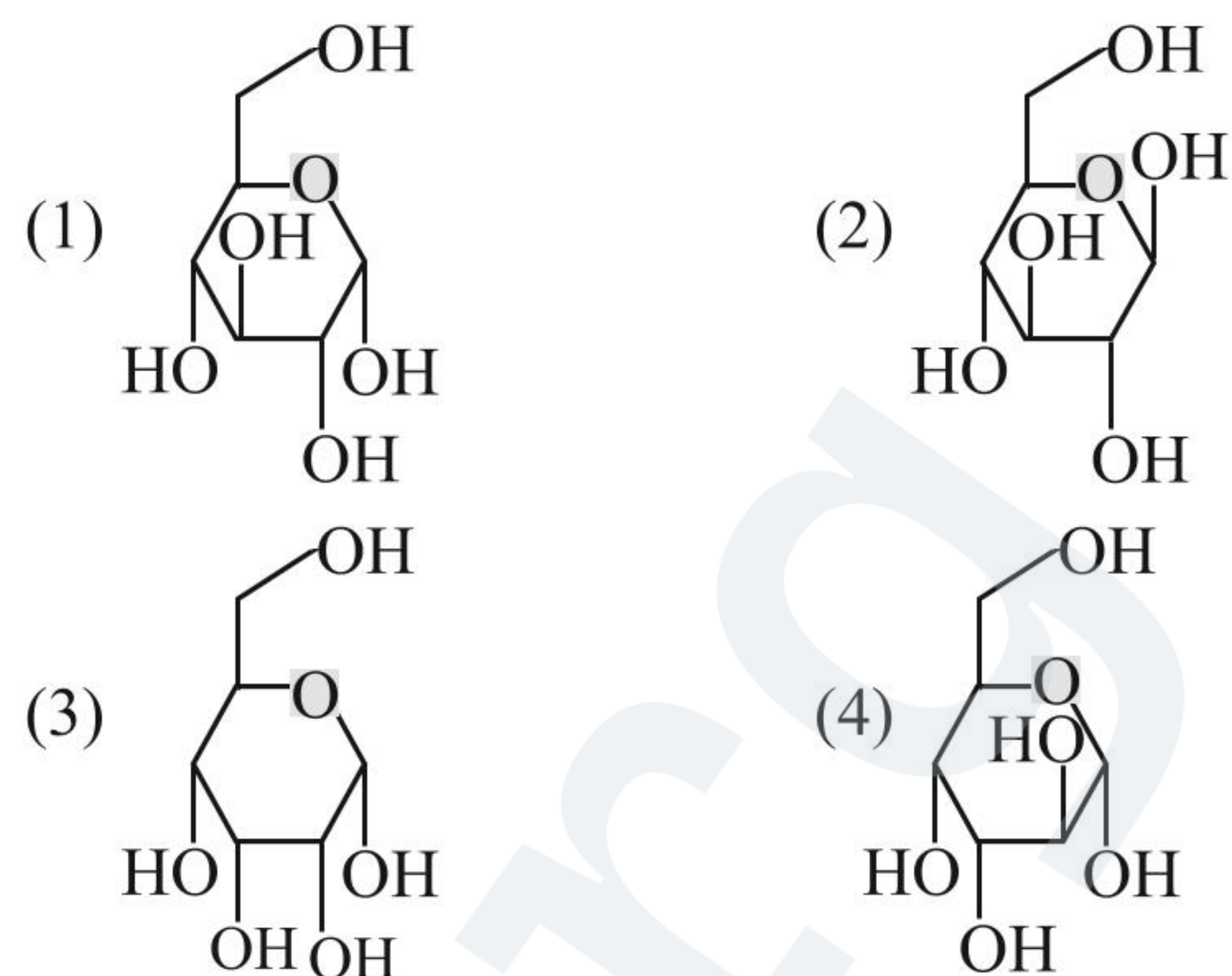
60. Which of the following gives an optically inactive aldaric acid on oxidation with dilute HNO_3 acid?



61. Gluconic acid is not obtained in



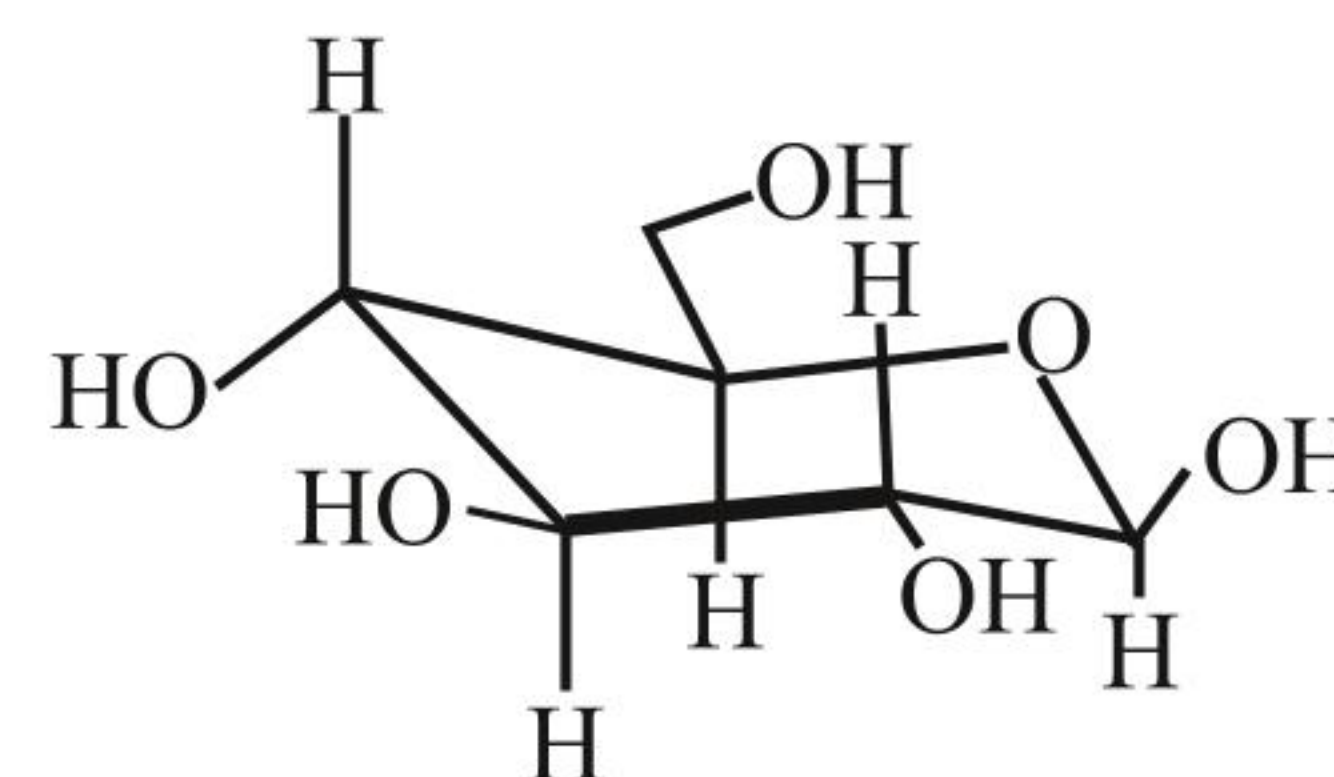
62. Which of the following structures represents α -D-glucopyranose?



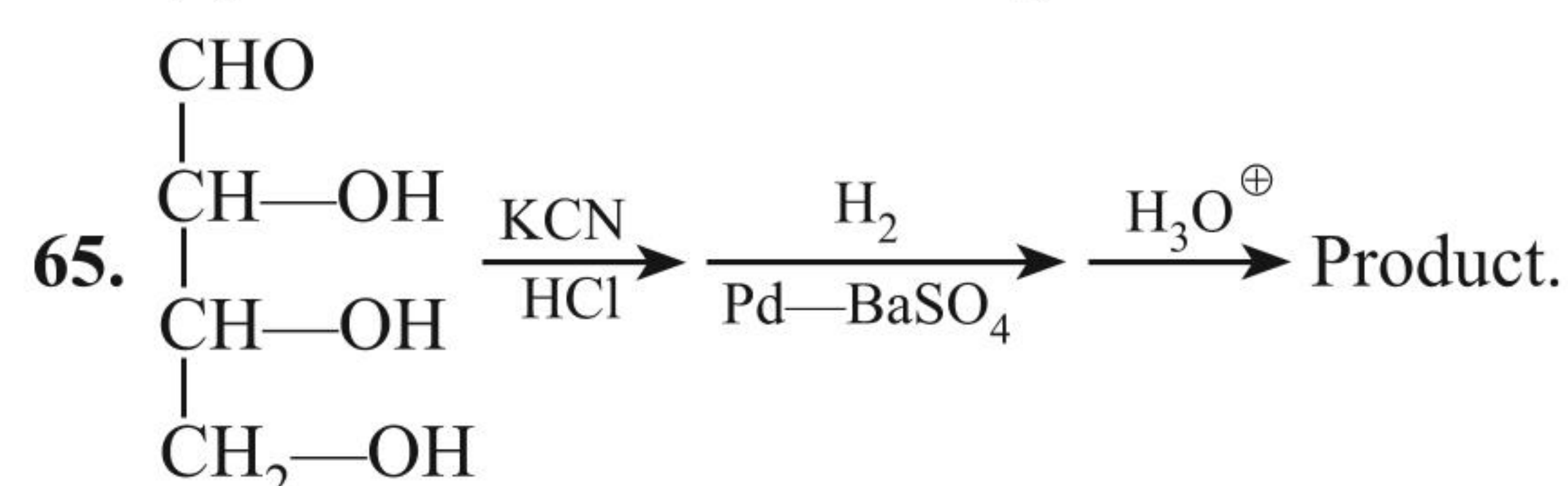
63. To determine the size of ring of glycosides, a scientist use periodic acid on treating with sample glycosides. He obtained one mole compound 'X' which reduces Tollen's reagent (unique behaviour in its category). This suggests:

- (1) Pyranoside form in glycoside
(2) Furanoside form in glycoside
(3) Open chain structure
(4) Insufficient data

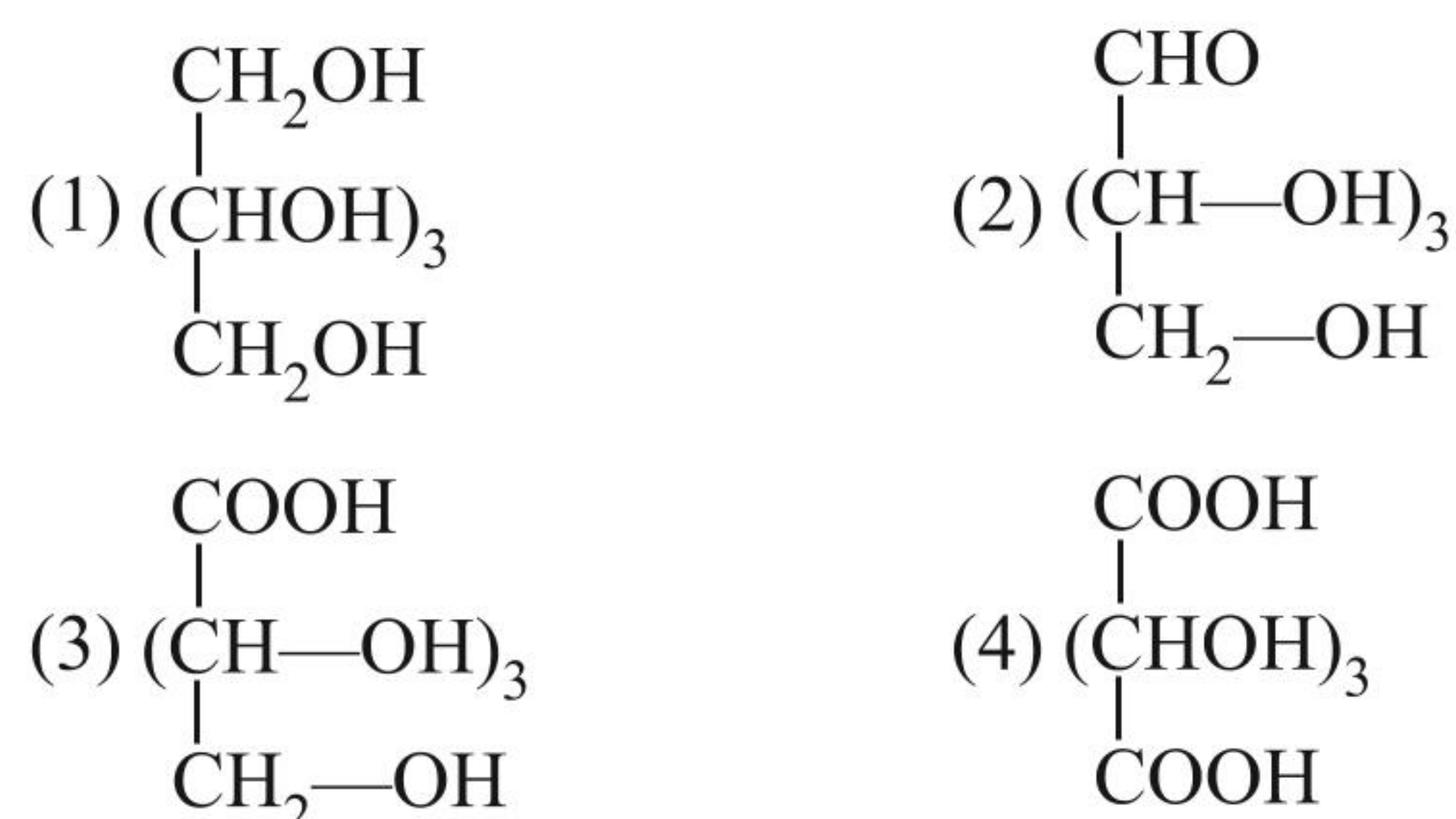
64. The incorrect statement regarding the following compound is:



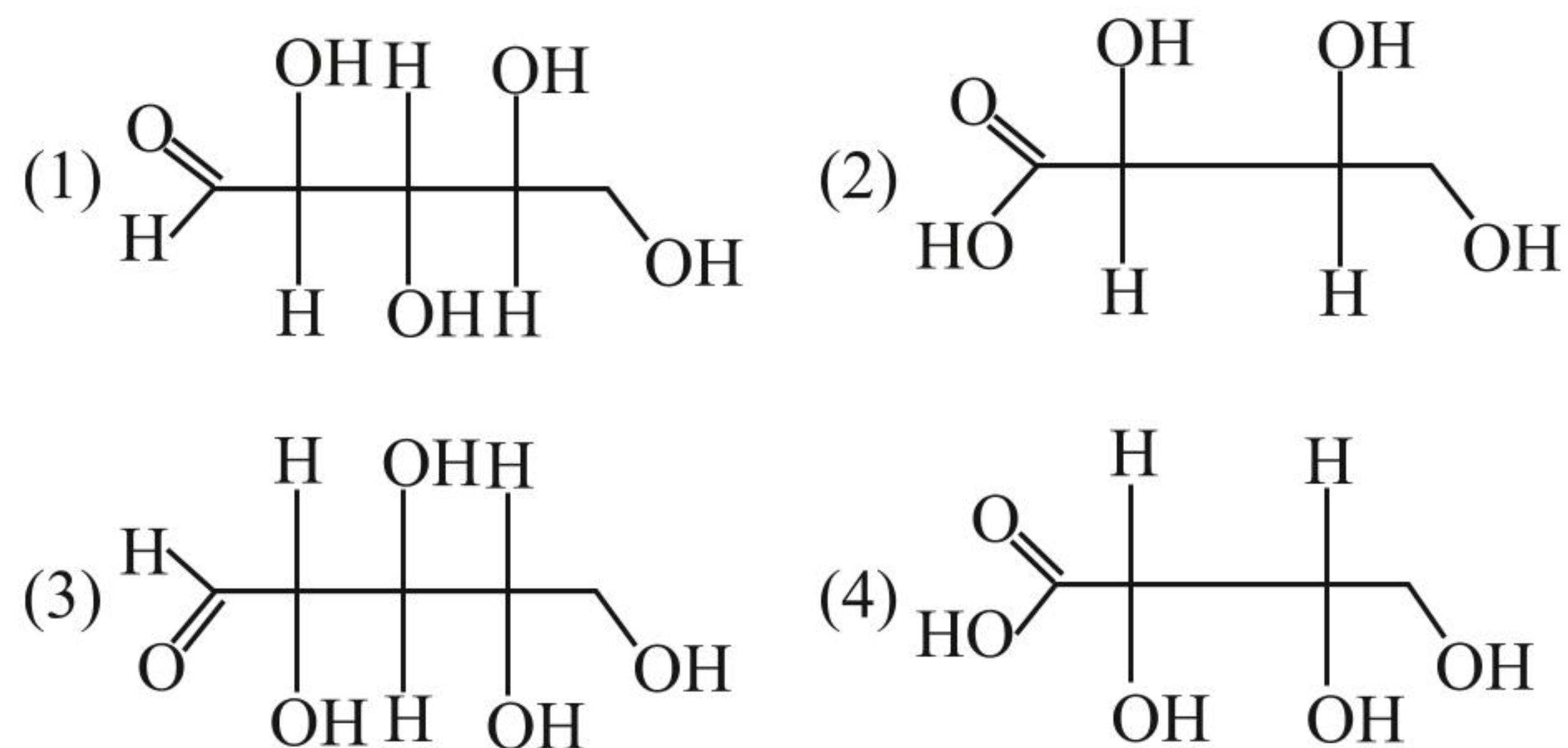
- (1) It is β -pyranose.
(2) It contains hemi acetal group.
(3) It is most stable aldohexose.
(4) It can reduce Schiff's reagent.



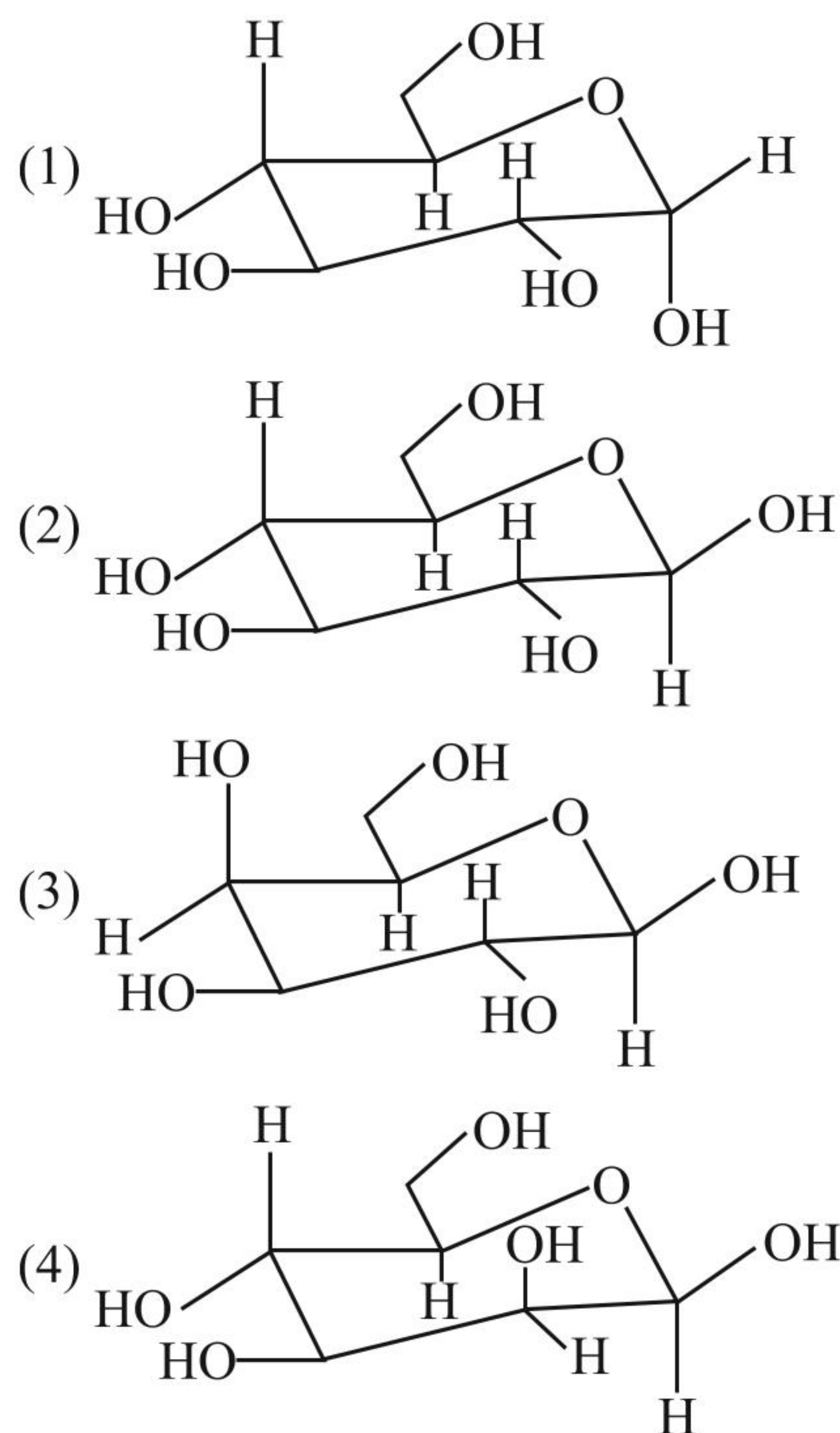
Find out final product:



66. Which of the following compounds is D-aldopentose?



67. Which is correct structure of β -D-glycopyranose ?



Polysaccharides

68. Cellulose is a linear polymer of:

- (1) α -D-Glucose (2) β -D-Glucose
(3) α -D-Fructose (4) β -L-Glucose

69. The disaccharide that is constituted of two glucose unit is:

- (1) Lactose (2) Maltose
(3) Sucrose (4) Ribose

70. The carbohydrate present in milk:

- (1) Sucrose (2) Maltose
(3) Lactose (4) Cellobiose

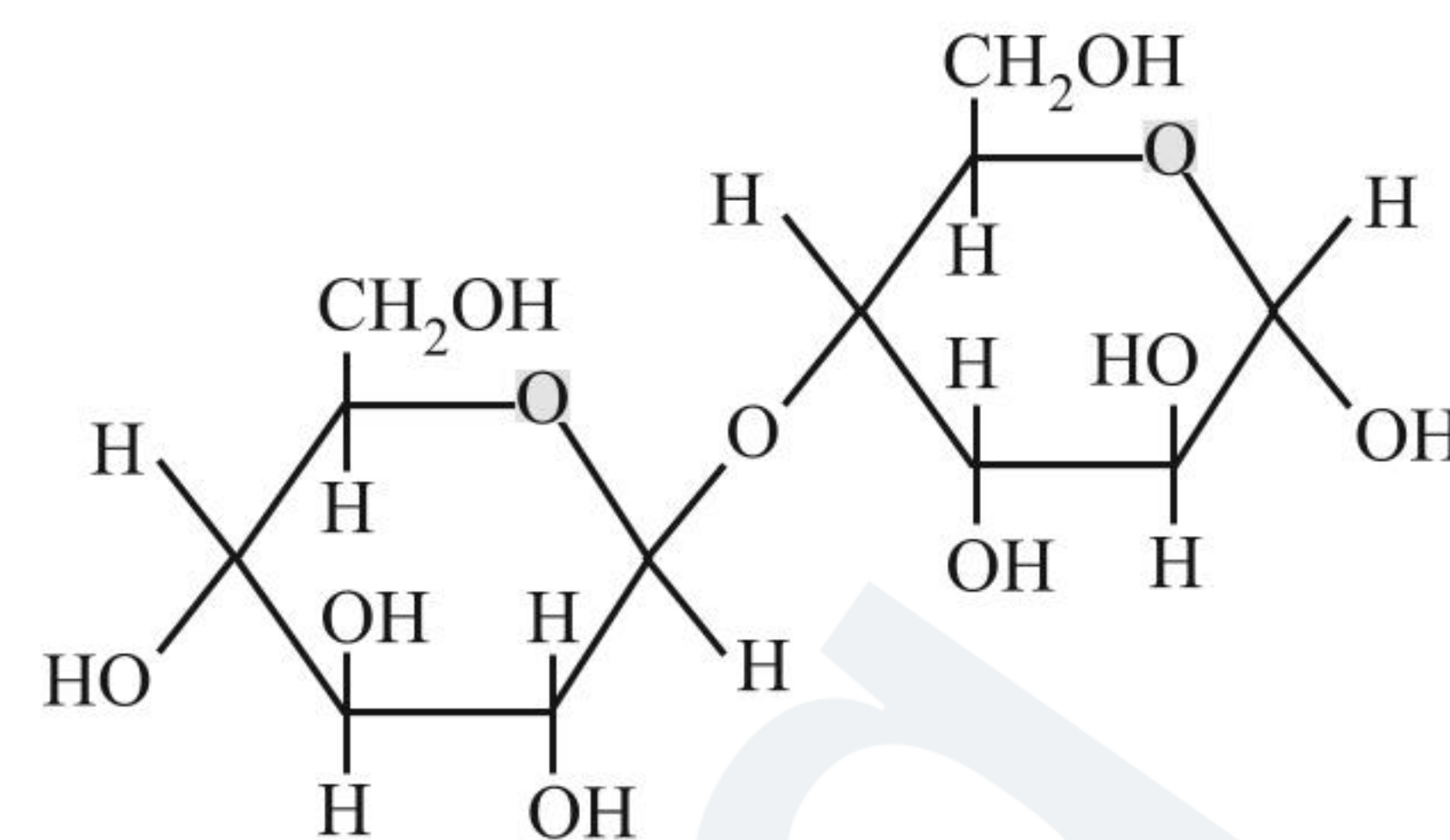
71. Cane sugar on hydrolysis gives:

- (1) Glucose and Galactose (2) Glucose only
(3) Glucose and Fructose (4) Fructose only

72. Which of the following is not a reducing sugar ?

- (1) Sucrose (2) Galactose
(3) Glucose (4) Lactose

73. The incorrect statement regarding following compound (Y) is:

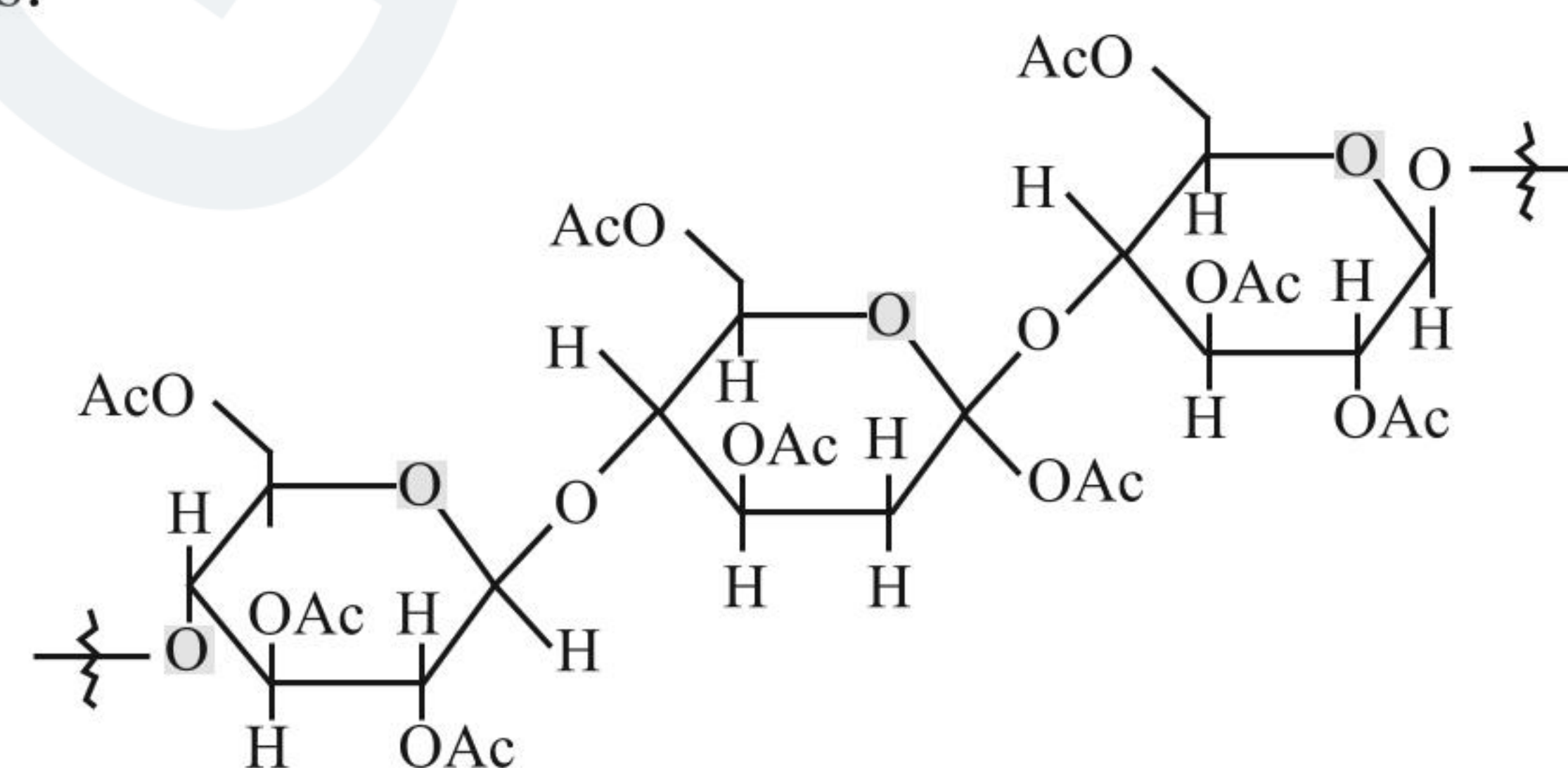


- (1) it is a reducing sugar.
(2) Can show mutarotation.
(3) Consumes 4 moles of HIO_4 .
(4) It is known as maltose.

74. Which one of the following carbohydrates will show mutarotation?

- (1) Sucrose (2) Starch
(3) Cellulose (4) Maltose

75. The correct statement regarding the following compound is:



- (1) Product can be obtained on acylation of starch.
(2) It contains β -1, 4 glycosidic linkage.
(3) It is water soluble compound.
(4) It is addition polymer known as cellulose.

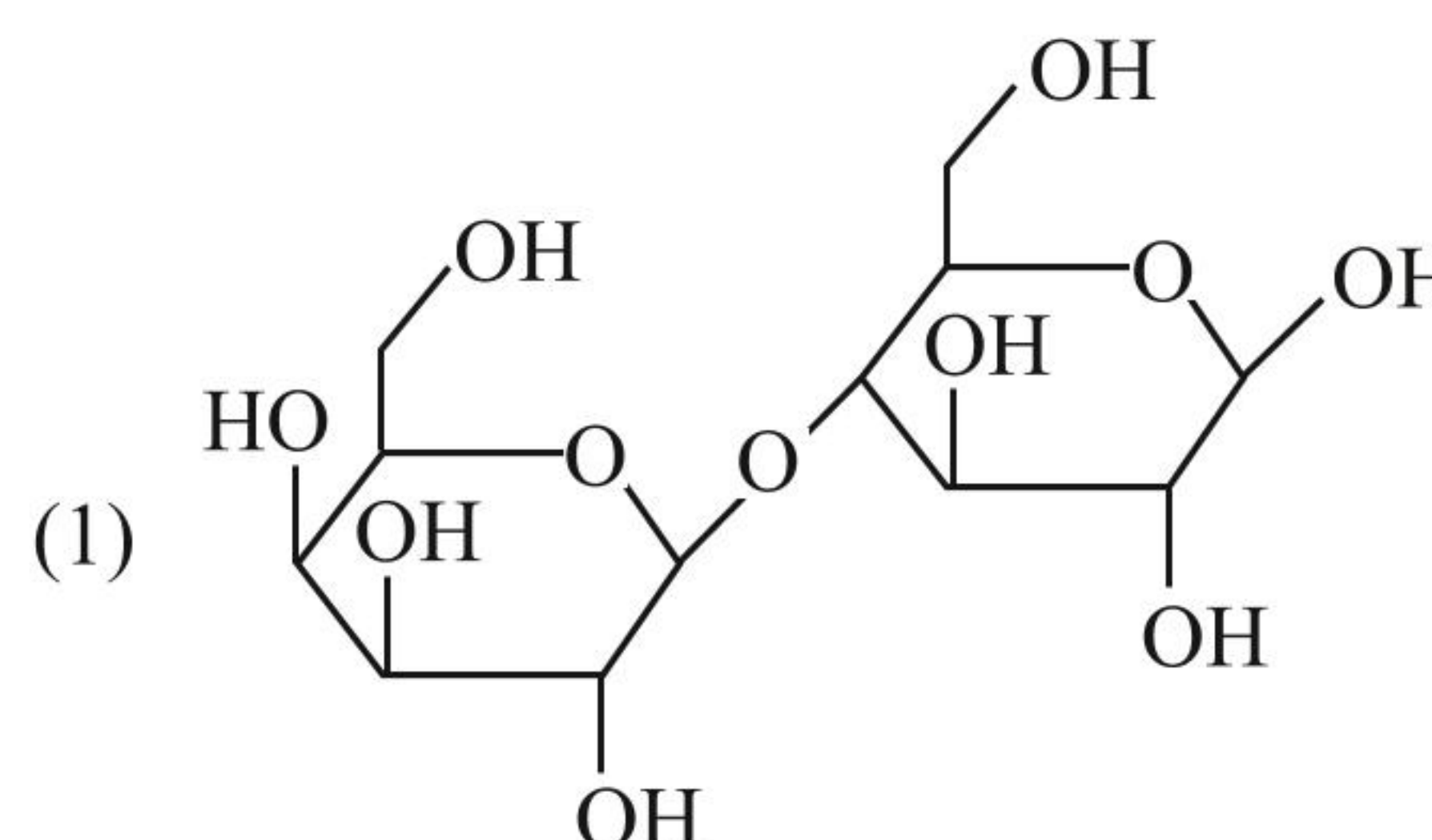
76. The maximum number of monosaccharide units present in oligosaccharides is:

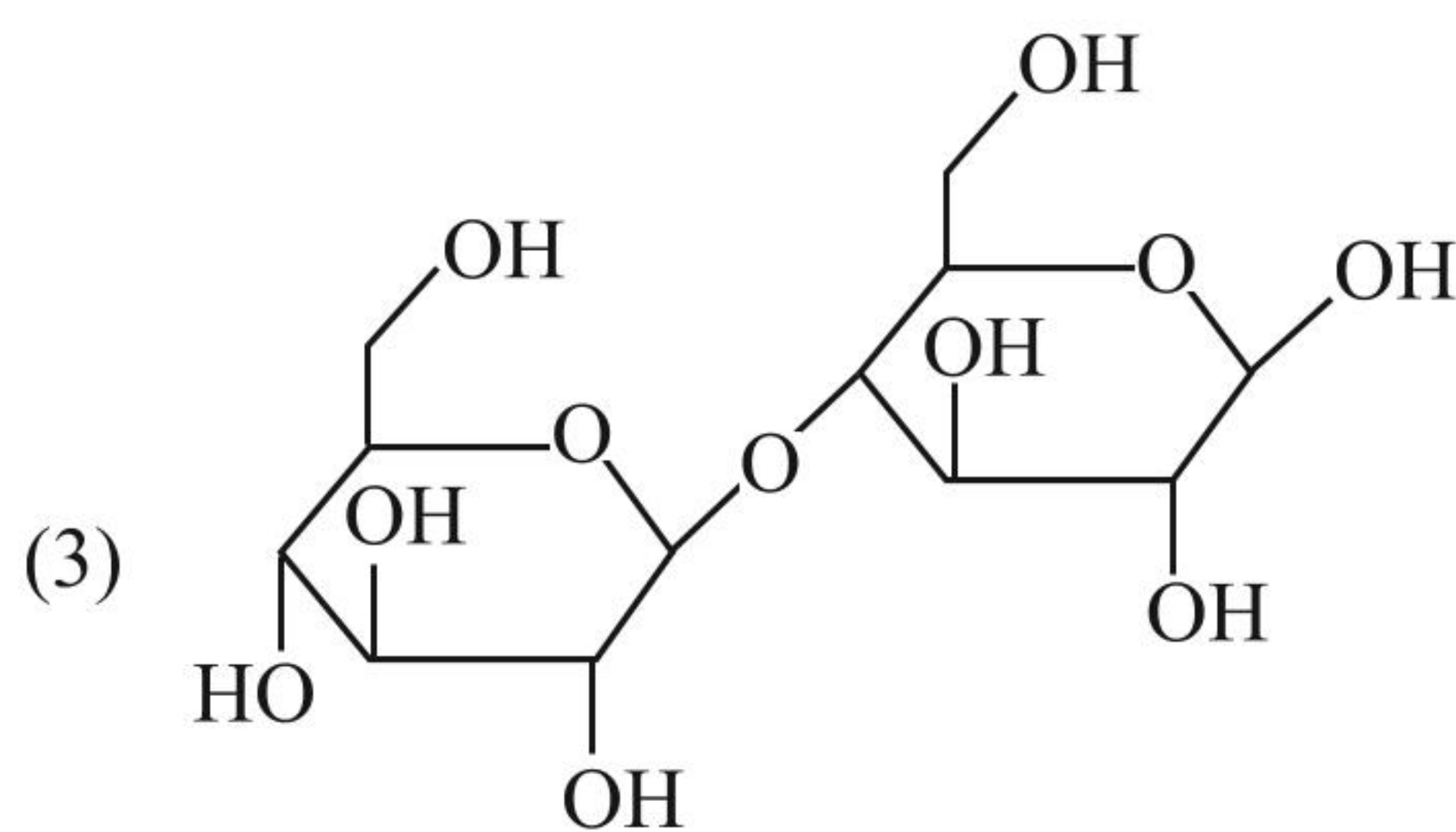
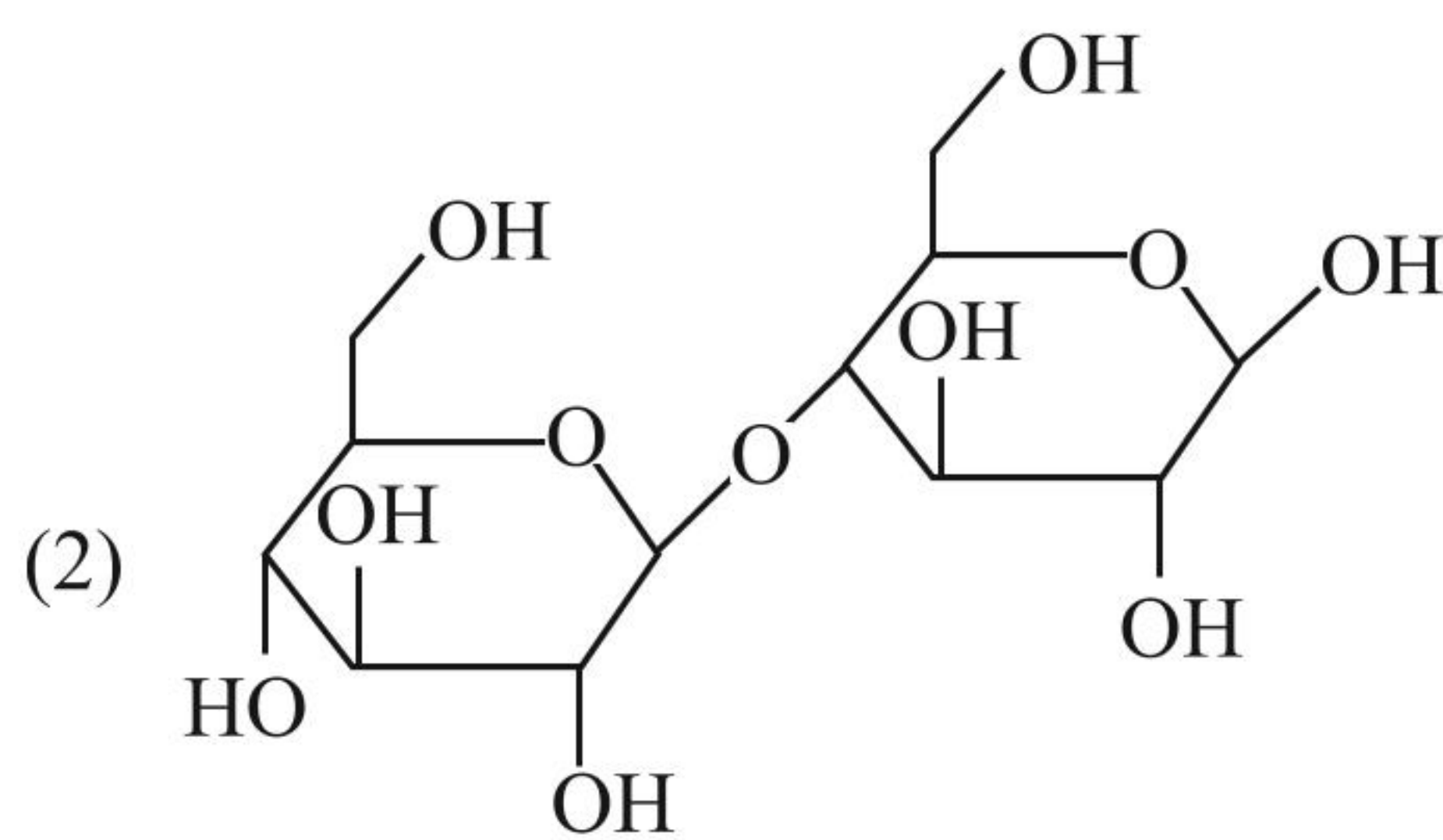
- (1) 8 (2) 15
(3) 10 (4) 40

77. The correct statement for sucrose is:

- (1) Both rings are in pyranose form.
(2) Both rings are in furanose form.
(3) Glucose ring is in furanose and fructose rings is in pyranose form.
(4) Glucose ring is in pyranose and fructose ring is in furanose form.

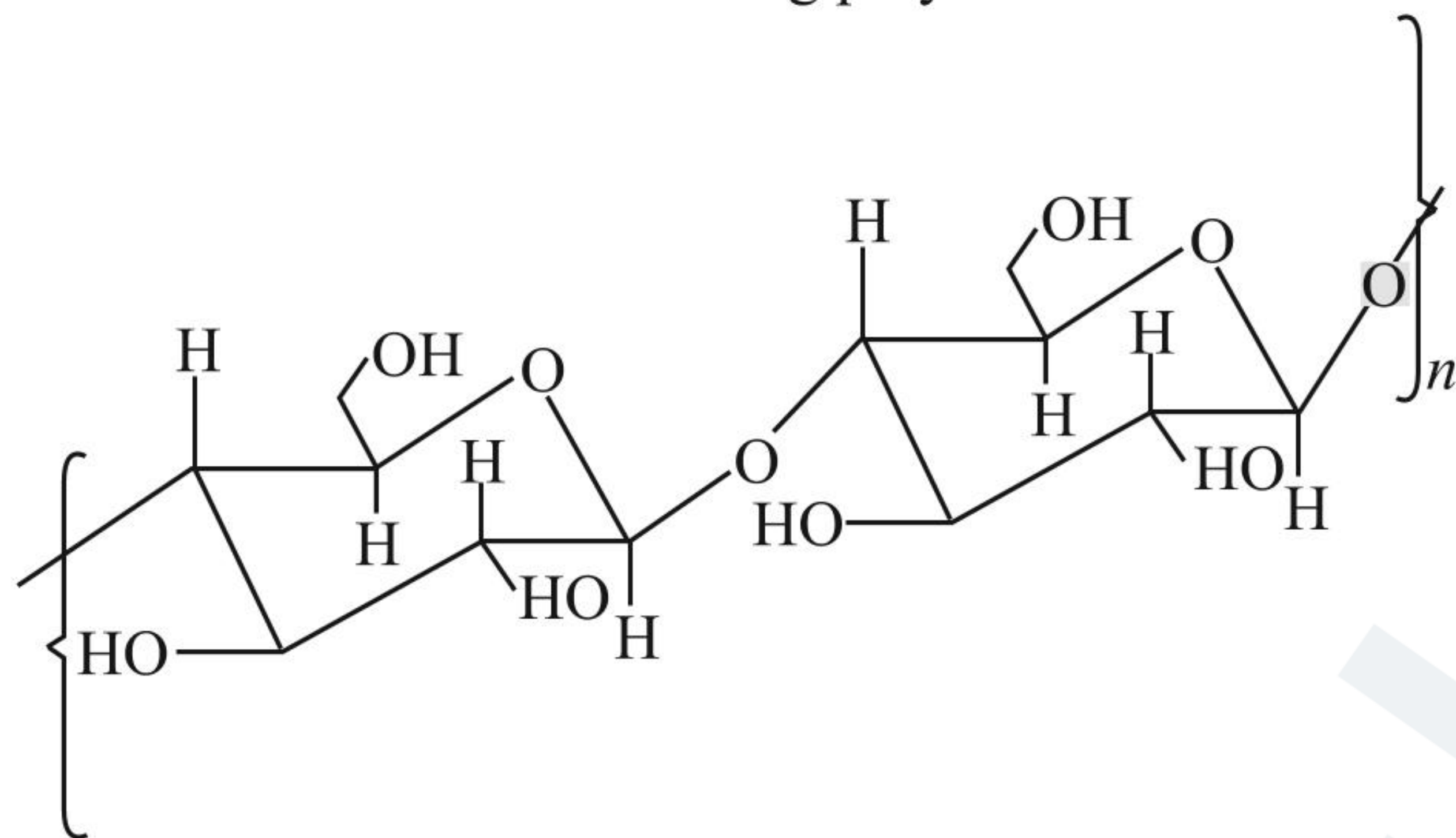
78. Find out the structure of lactose:





(4) None of these

79. The structure of the following polymer is:



- (1) Starch (2) Sucrose
(3) Cellulose (4) Maltose

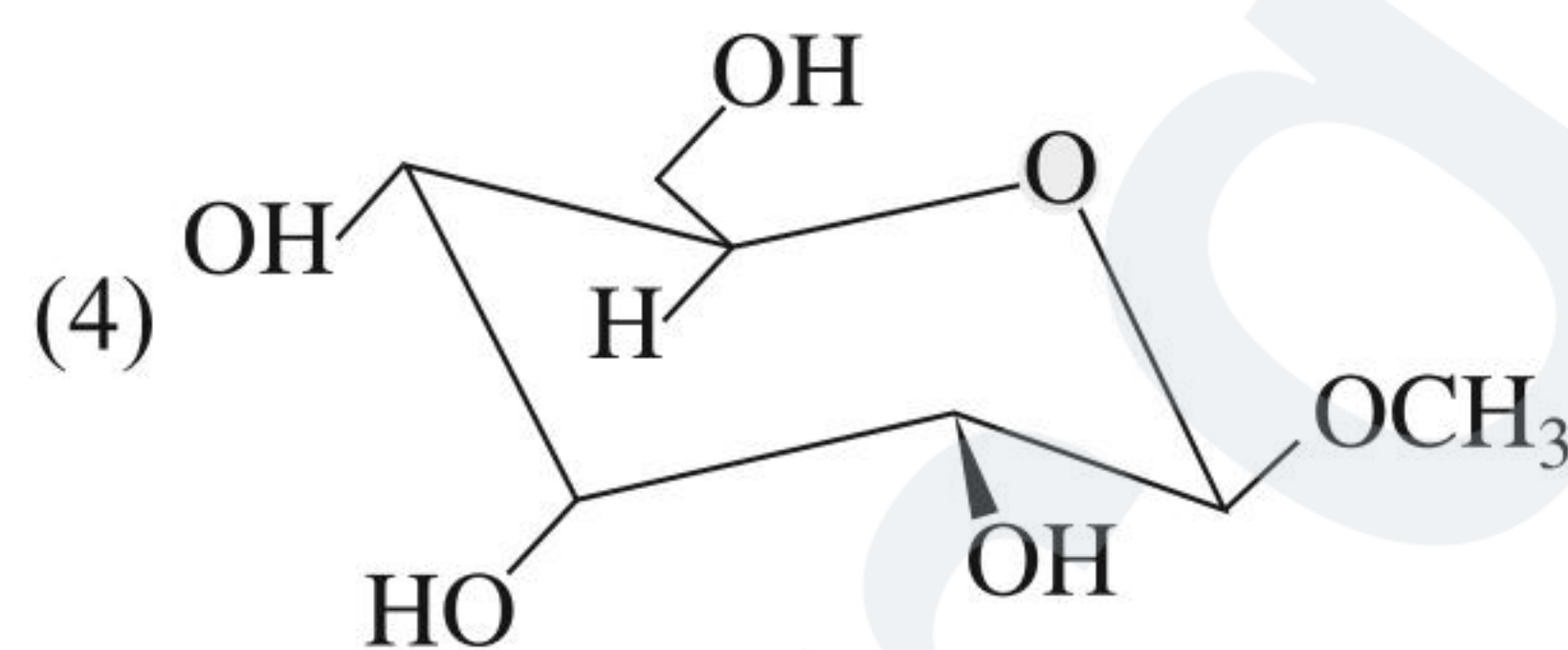
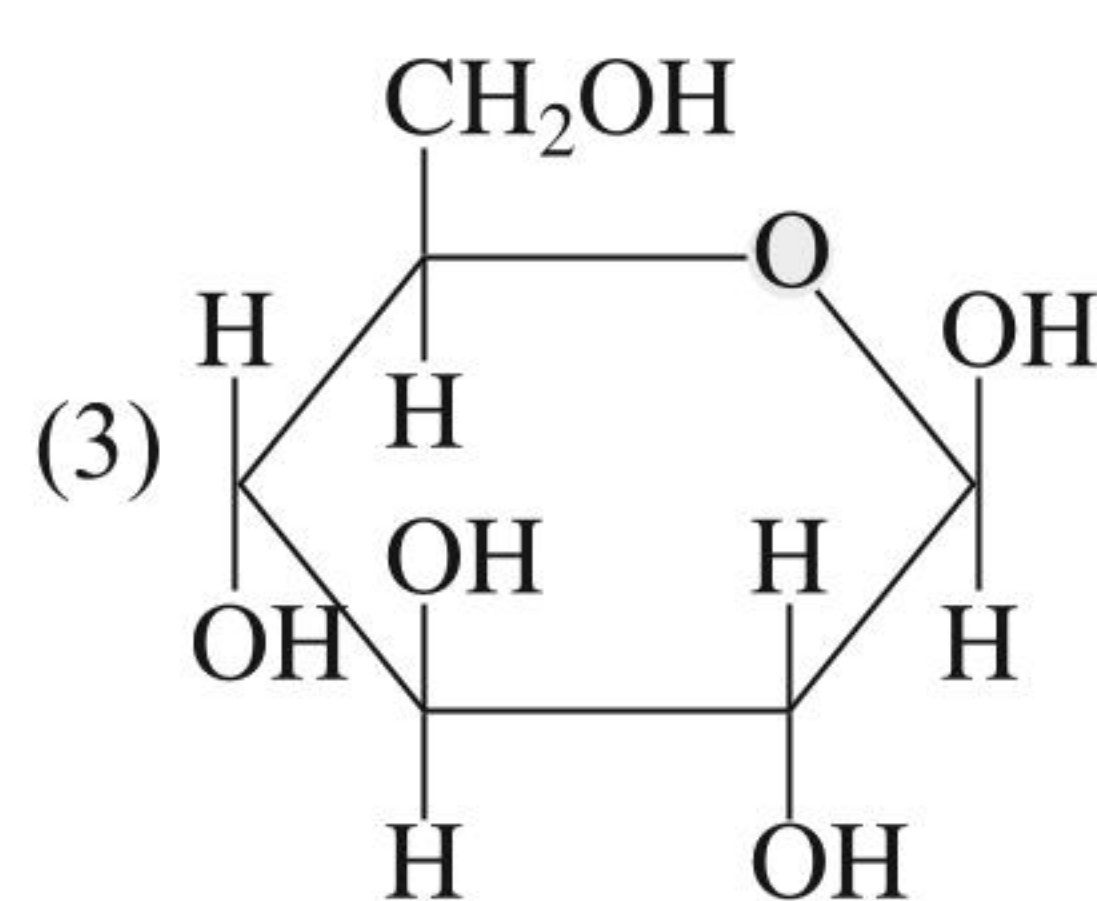
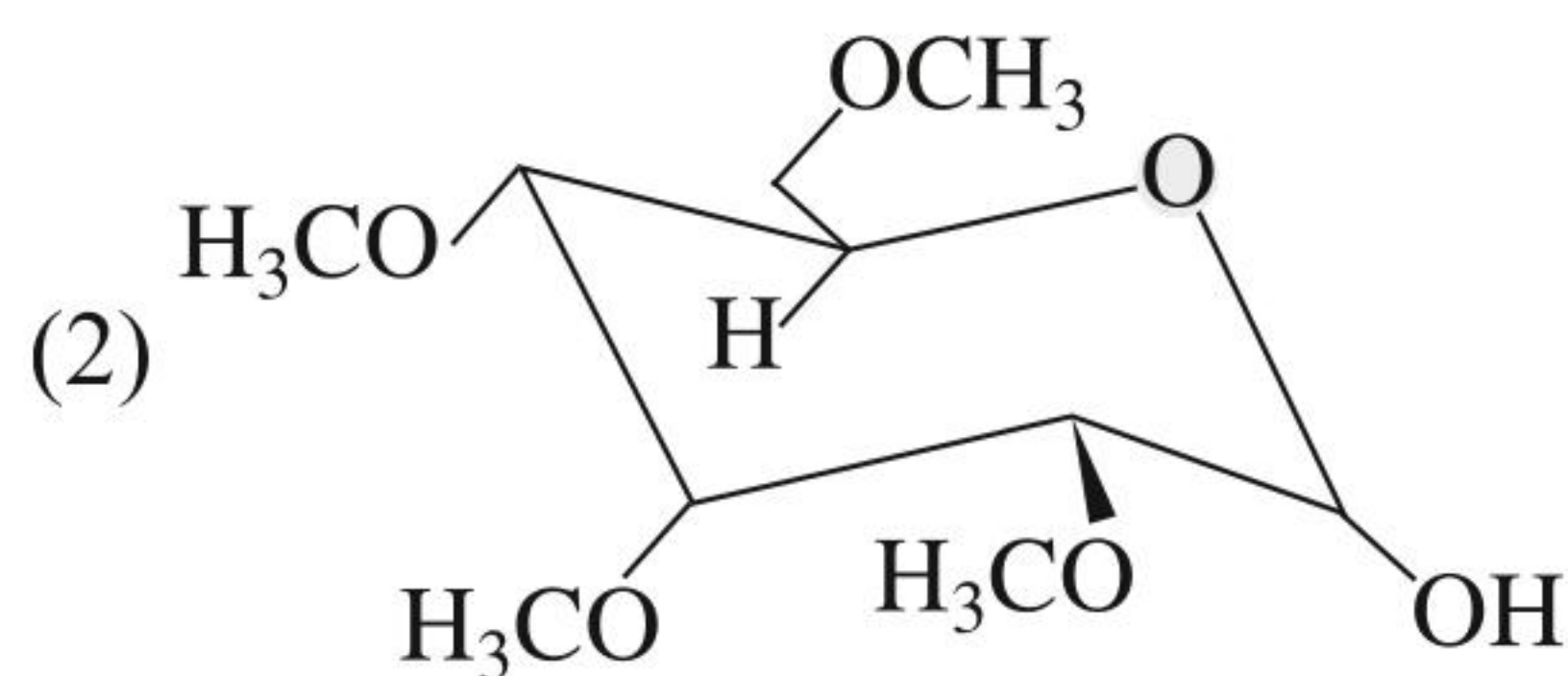
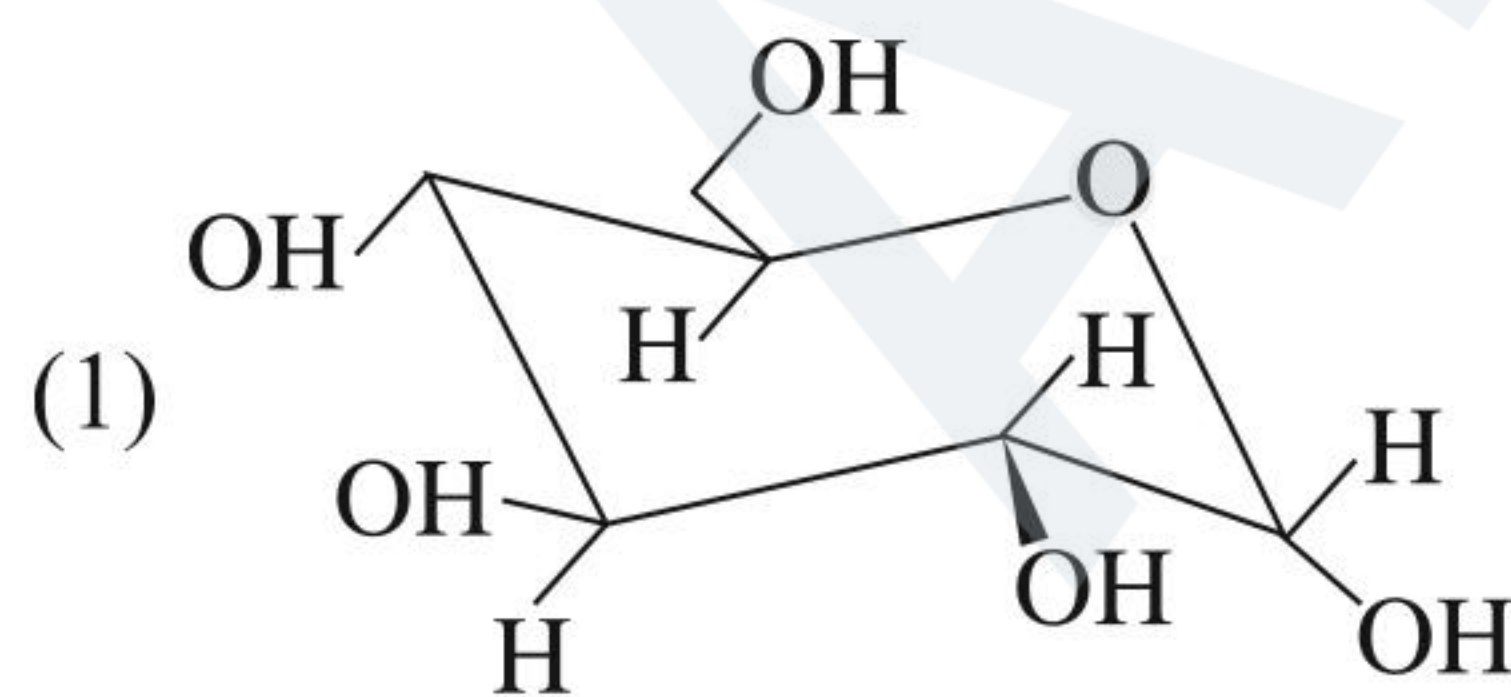
80. Maltase involves:

- (1) Decomposition of urea into NH_3 and CO_2 .
(2) Hydrolysis of cane sugar.
(3) Hydrolysis of maltose into glucose.
(4) Conversion of glucose into ethyl alcohol.

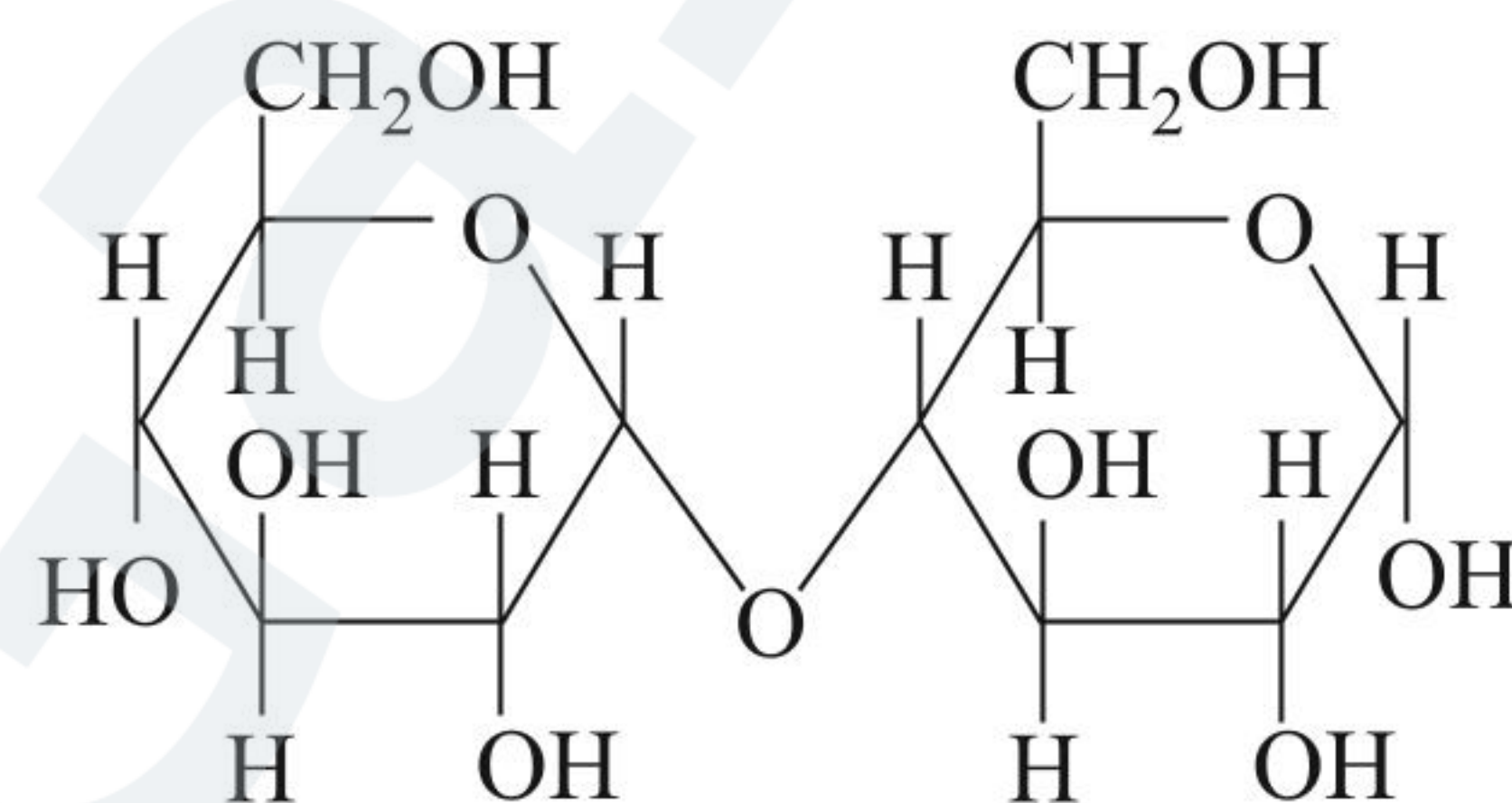
81. The optical rotation of the α -form of a pyranose is $+150.7^\circ$, that of the β -form is $+52.8^\circ$. In solution an equilibrium mixture of these anomers has an optical rotation of $+80.2^\circ$. The percentage of the α -form in equilibrium mixture is:

- (1) 28% (2) 32%
(3) 68% (4) 72%

82. Identify the non-reducing sugar:



83. How many aldose and ketose, and furanose and pyranose units are present in maltose?



- (1) 0 aldose, 2 ketose, 0 furanose, 2 pyranose
(2) 1 aldose, 1 ketose, 1 furanose, 1 pyranose
(3) 2 aldose, 0 ketose, 0 furanose, 2 pyranose
(4) 2 aldose, 0 ketose, 1 furanose, 2 pyranose

84. Which of the following statement regarding methyl- β -L-glucopyranoside is correct?

- (1) This glycoside is a reducing sugar
(2) This glycoside undergoes mutarotation in aqueous base
(3) This glycoside will undergoes no reaction when treated with excess $\text{CH}_3\text{I}/\text{Ag}_2\text{O}$
(4) This glycoside will be hydrolyzed to the cyclic hemiacetal in dilute aqueous acid

85. Which is the correct statement?

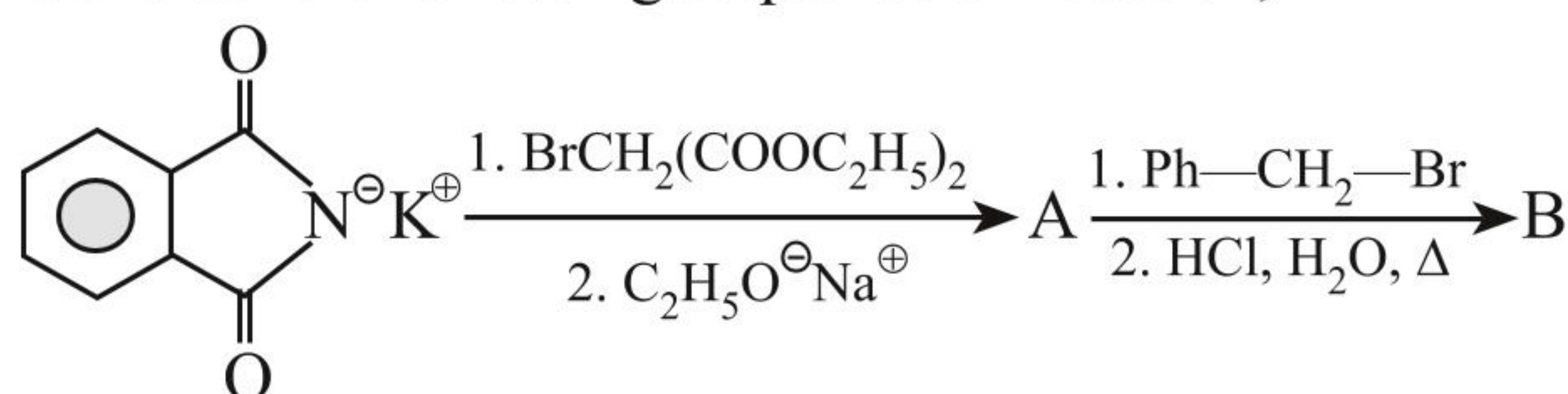
- (1) Starch is a polymer of α -glucose.
(2) Amylose is a component of cellulose.
(3) Proteins are composed of only one type of amino acids.
(4) In cyclic structure of furanose, there are four carbon atoms and one oxygen atom.

86. Cellulose is a straight-chain polysaccharide composed of only:

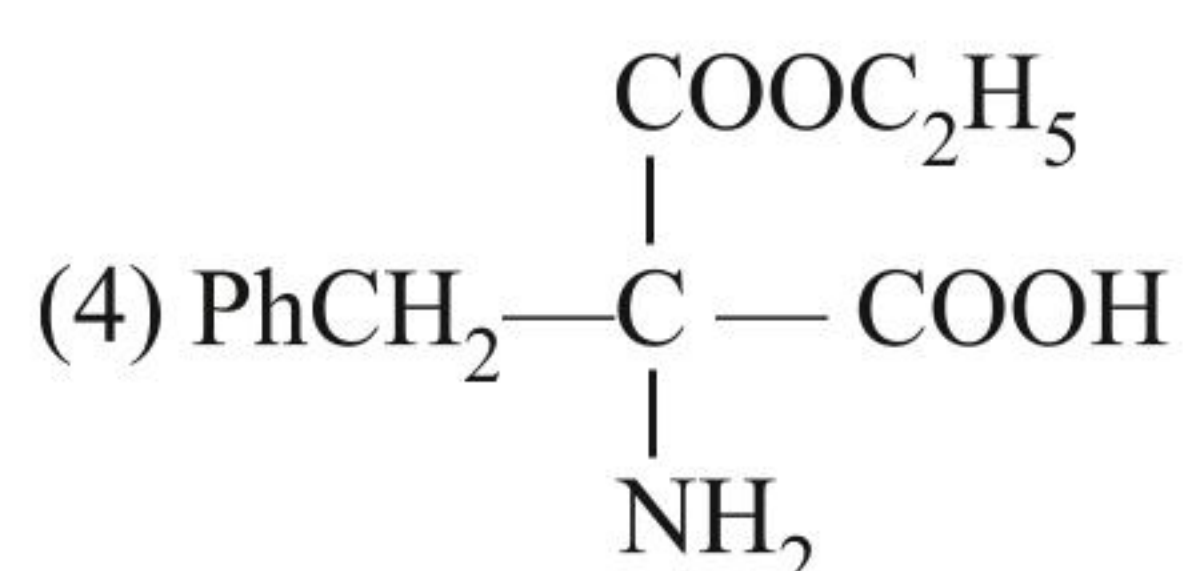
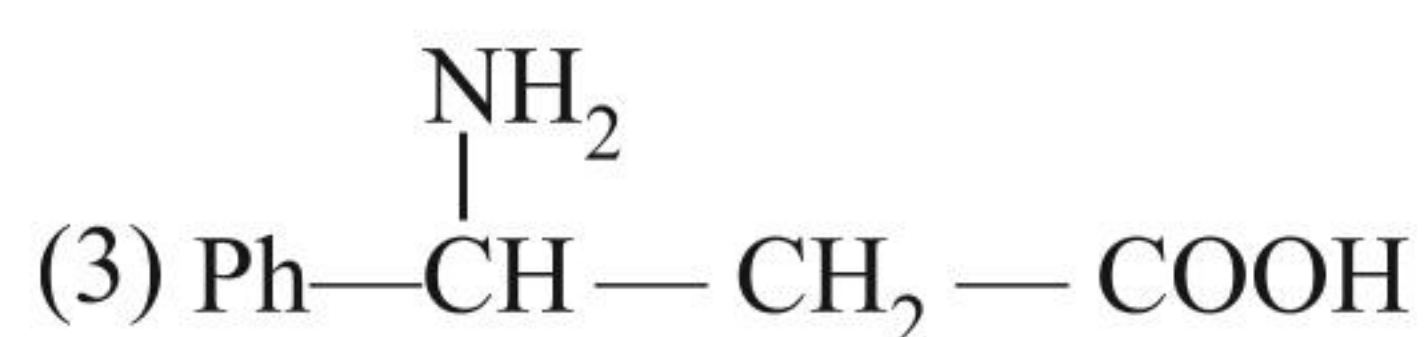
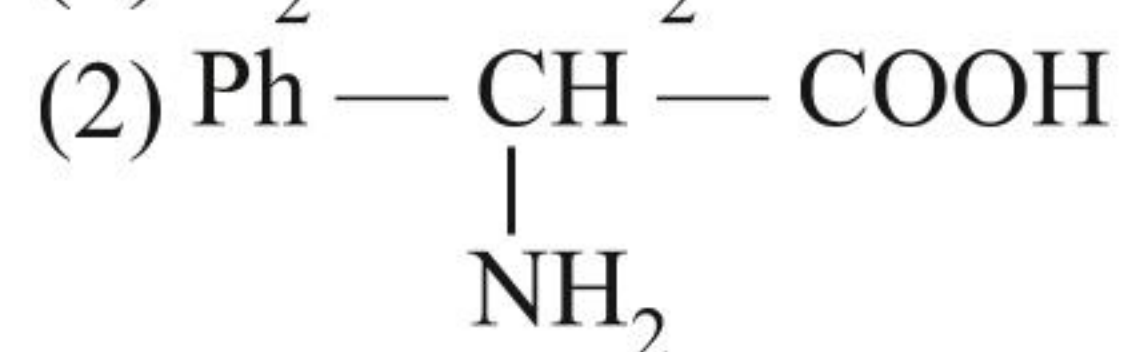
- (1) D-Glucose units joined by α -glycosidic linkage.
(2) D-Glucose units joined by β -glycosidic linkage.
(3) D-Galactose units joined by α -glycosidic linkage.
(4) D-Galactose units joined by β -glycosidic linkage.

Amino acids, Proteins, Nucleic acid and Vitamins

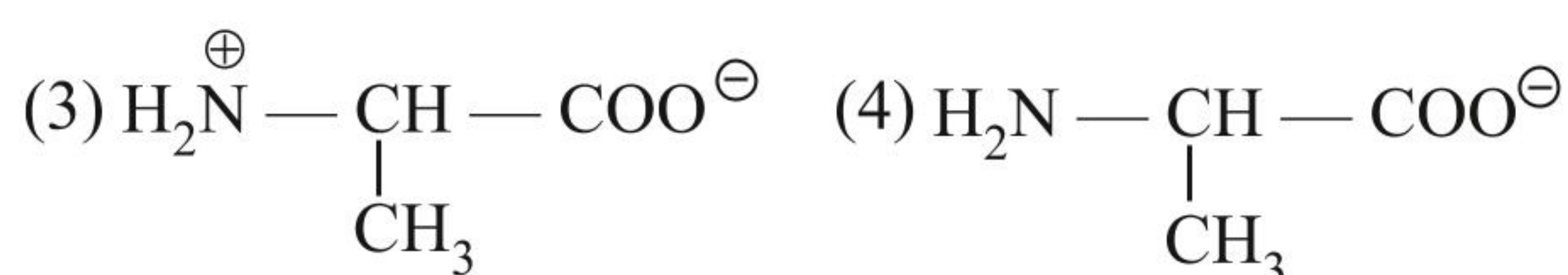
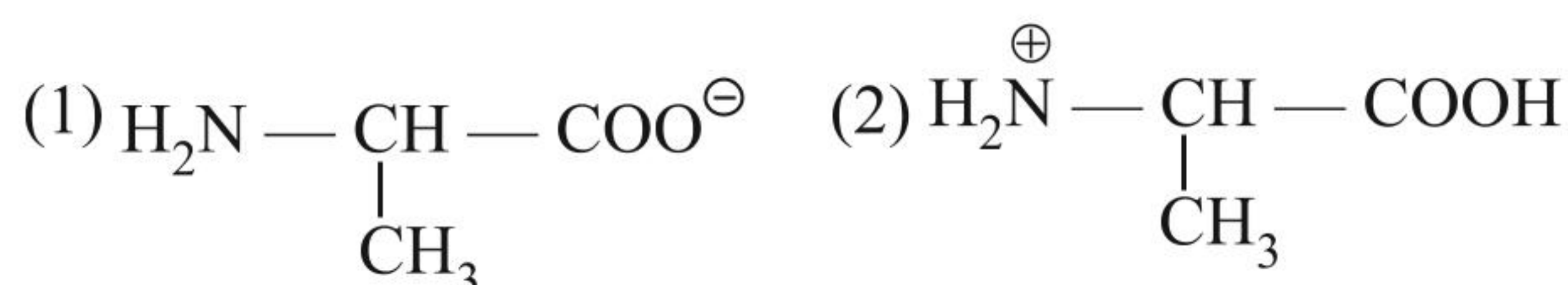
87. Consider the following sequence of reaction,



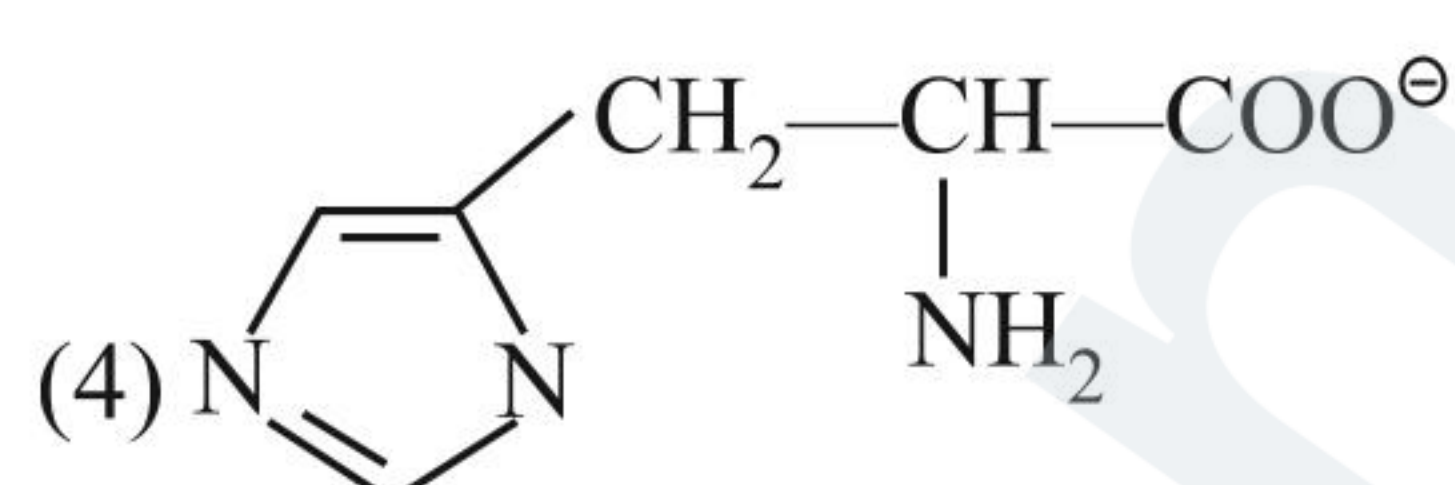
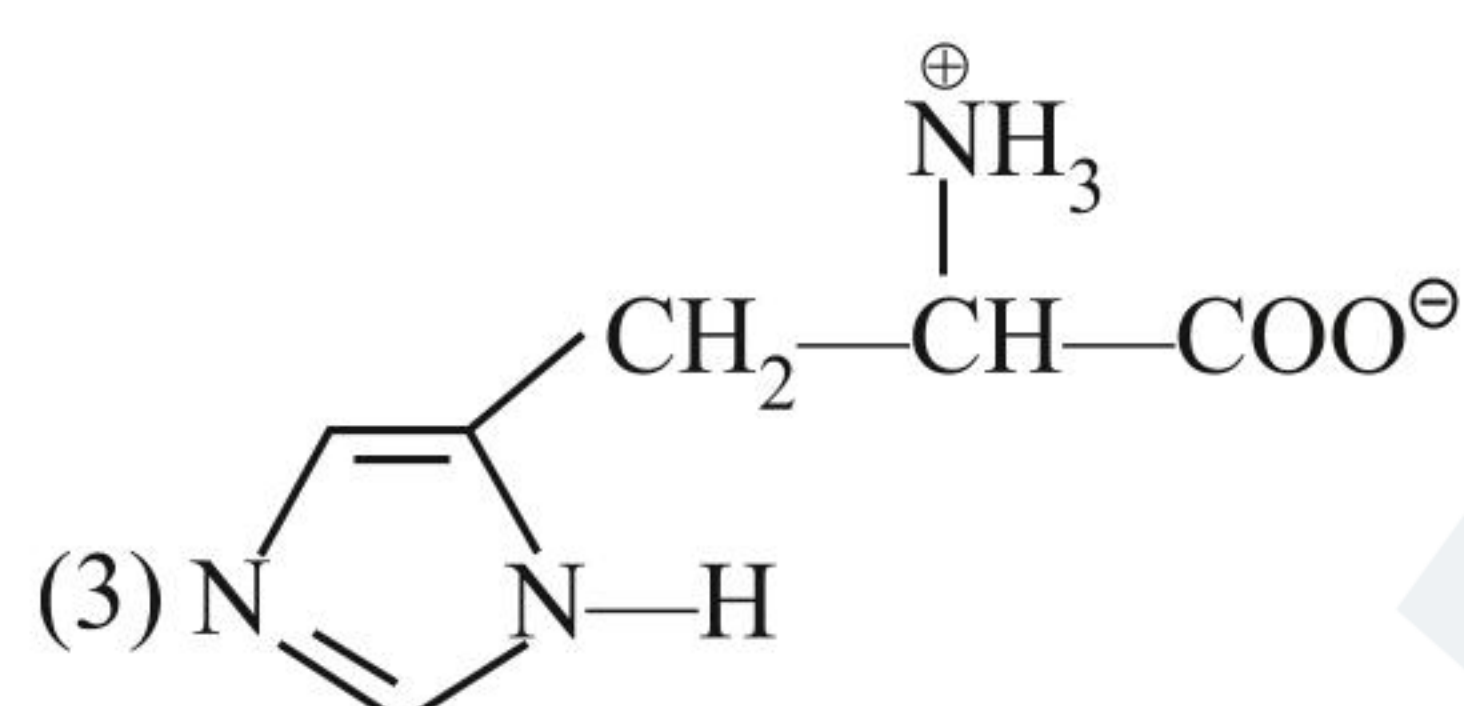
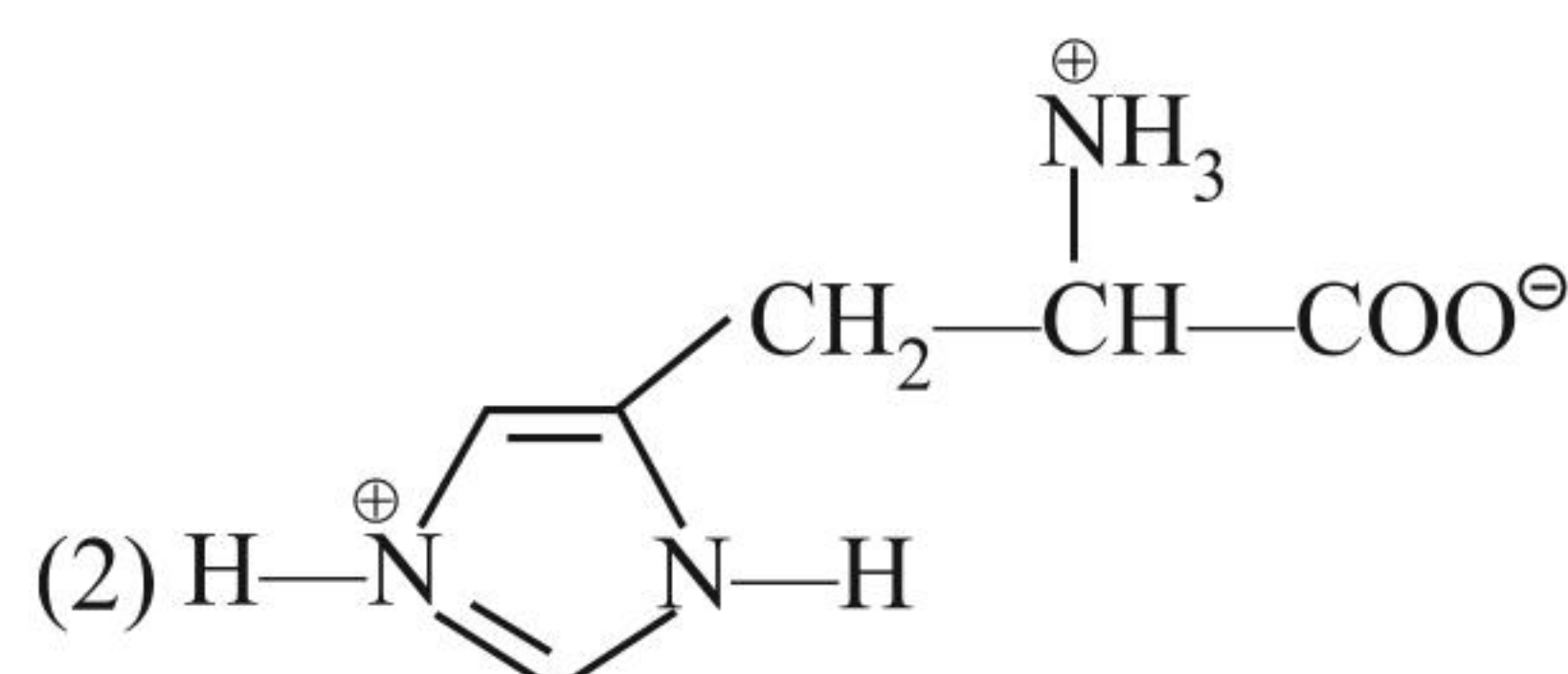
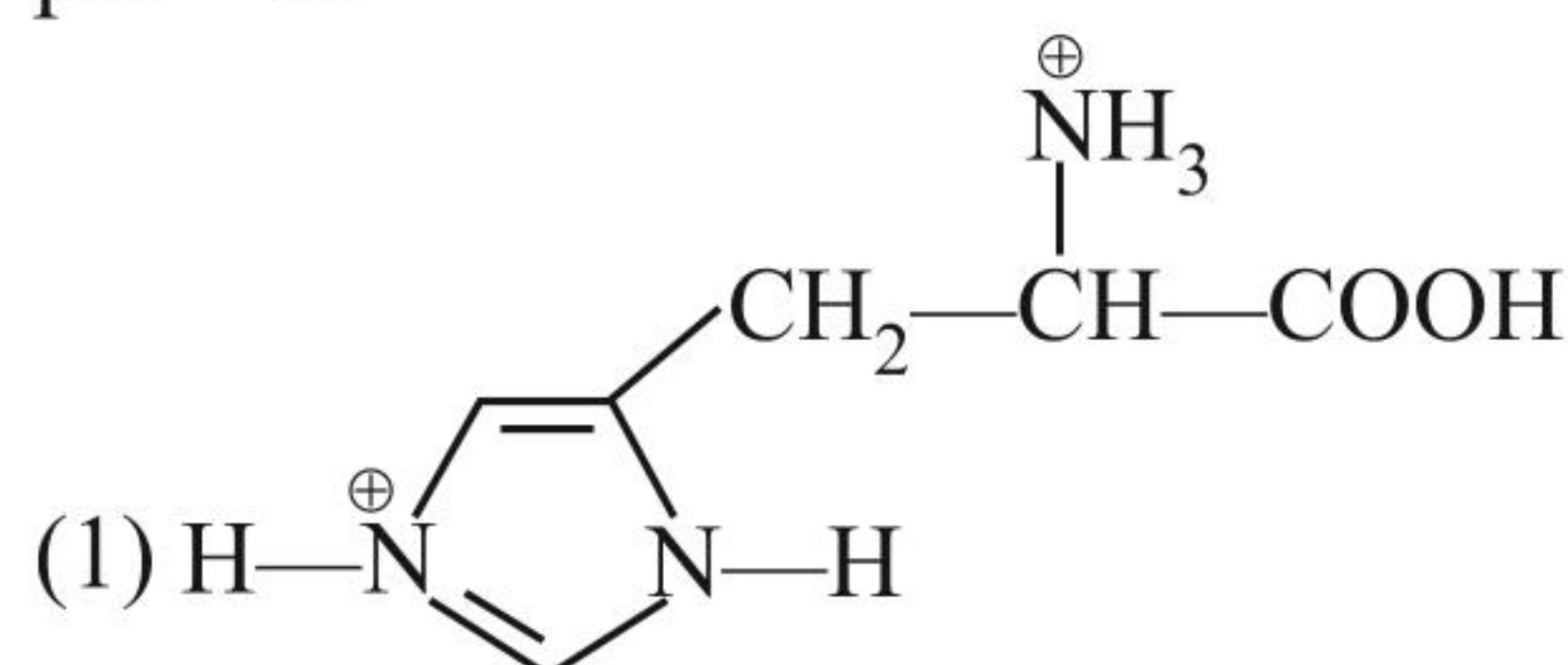
The major final product (B) is:



88. Alanine at its isoelectric point, exist in solution as:



89. Which of the following is correct structure of histidine at $\text{pH} = 0$?



90. Which of the following statements most correctly defines the isoelectric point?

(1) The pH at which all molecular species are ionised and that carry the same charge.

(2) The pH at which all molecular species are neutral and uncharge.

(3) The pH at which half of the molecular species are ionised and the other half unionised.

(4) The pH at which negatively and positively charged molecular species are present in equal concentration.

91. α -Amino acids behave as crystalline ionic solid and have high melting point due to the presence of :

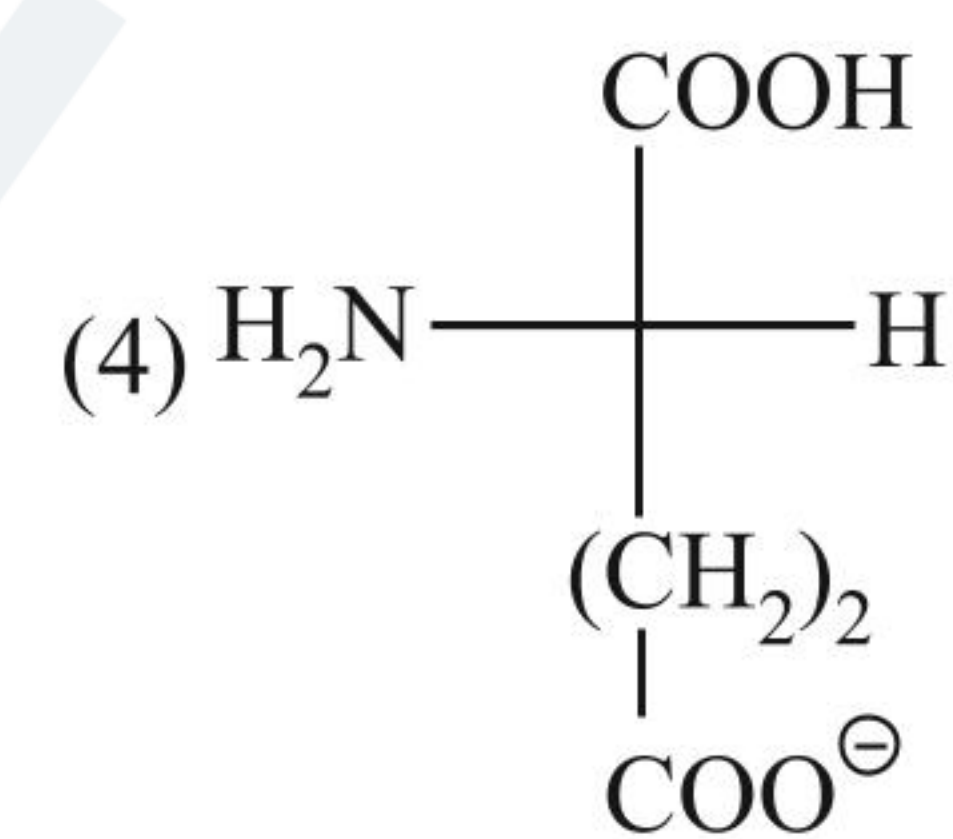
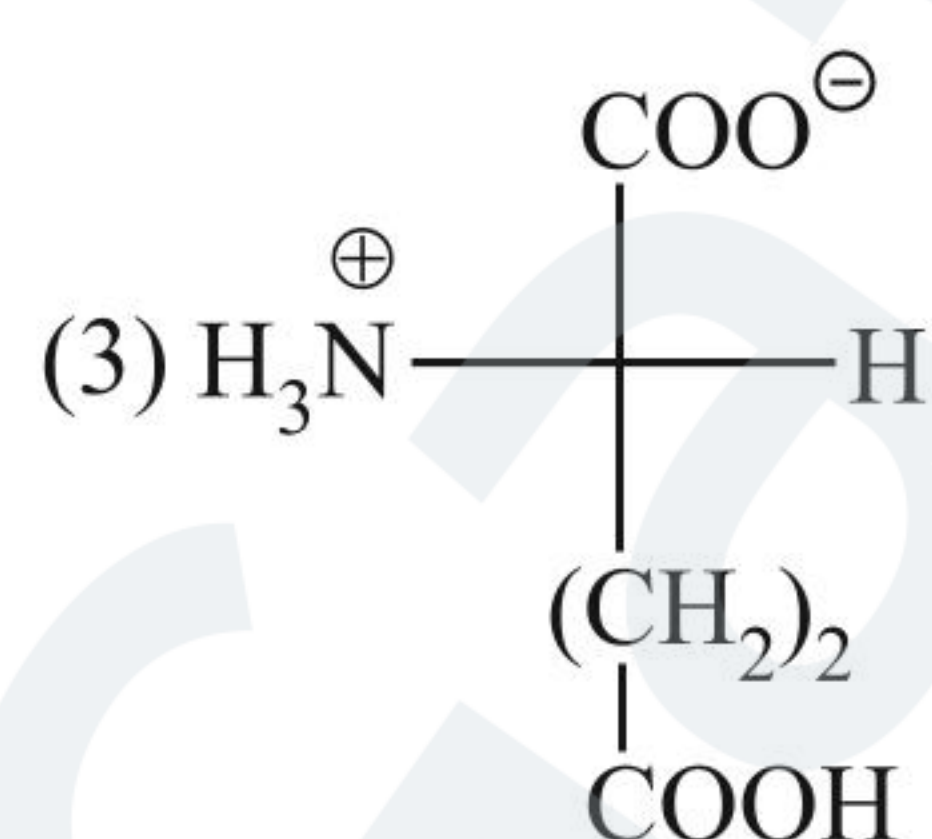
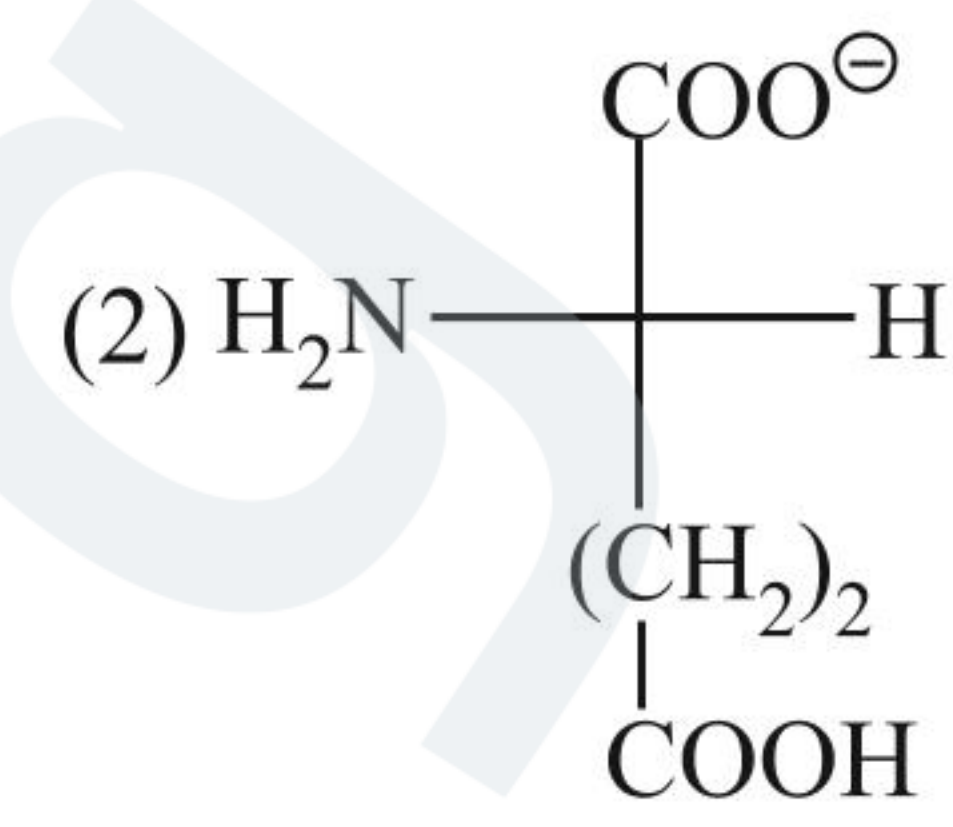
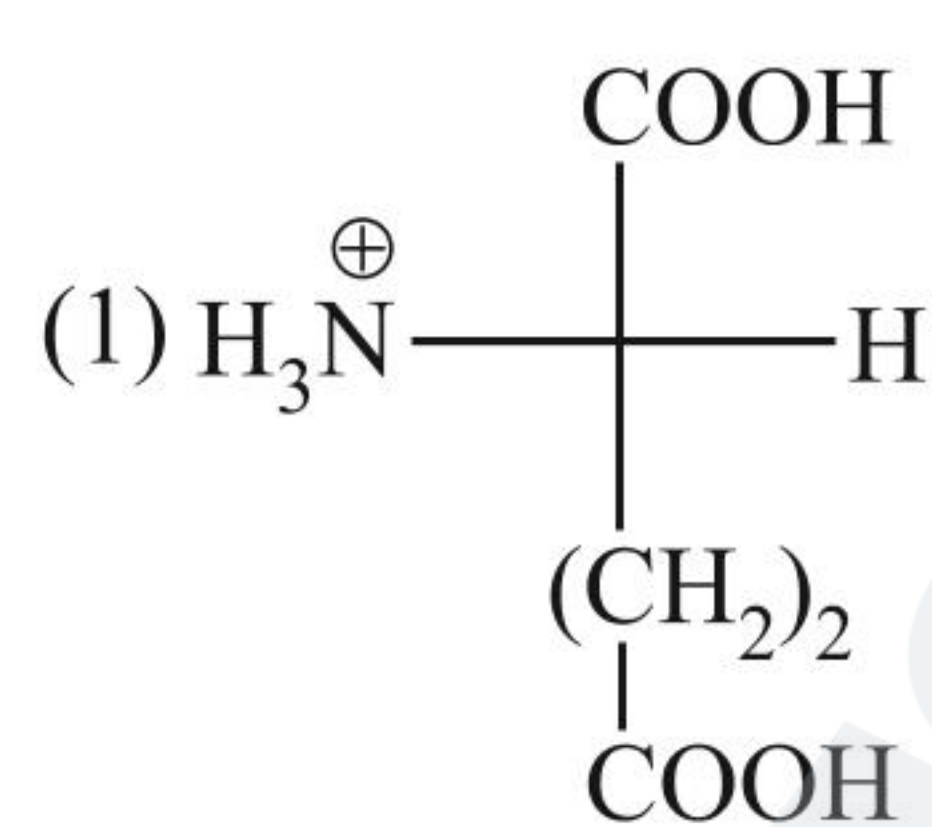
(1) $-\text{NH}_2$ group

(2) $-\text{COOH}$ group

(3) both $-\text{NH}_2$ and $-\text{COOH}$

(4) None of these

92. Which of the following is the major solute species in a solution of glutamic acid at $\text{pH} = 1.3$?



93. Biuret test is used for the detection of :

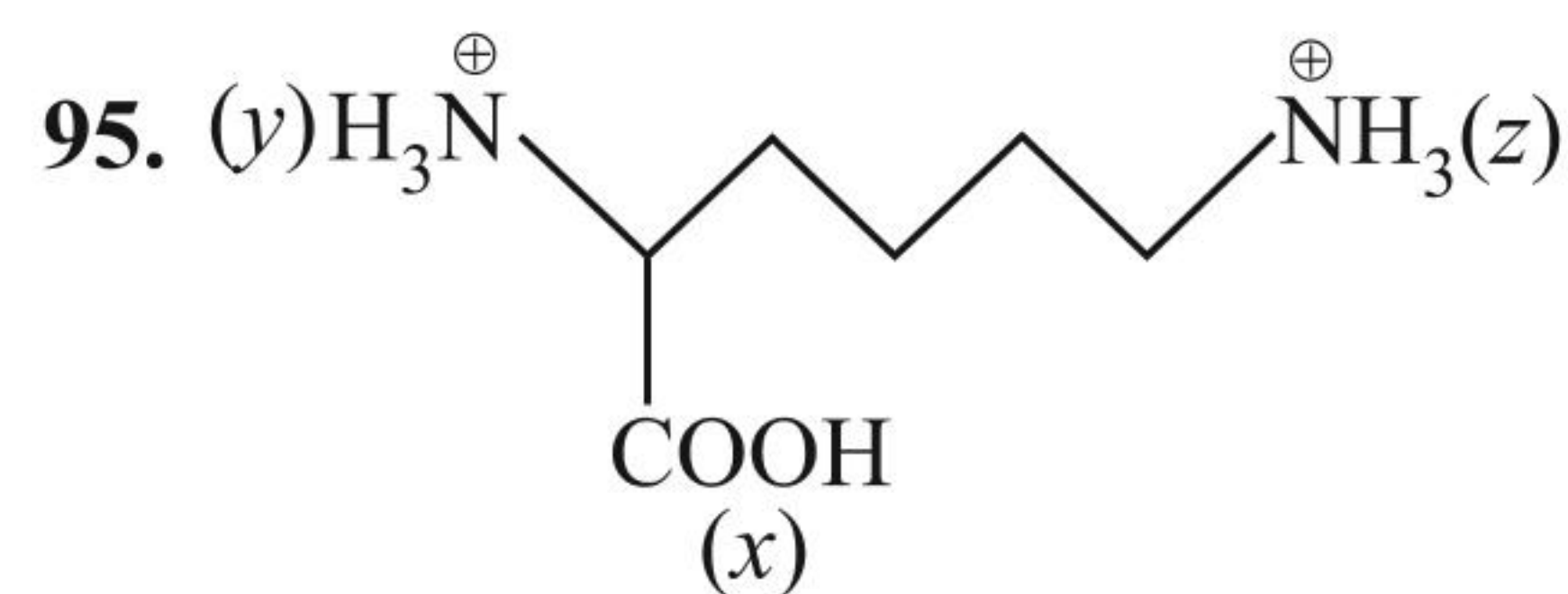
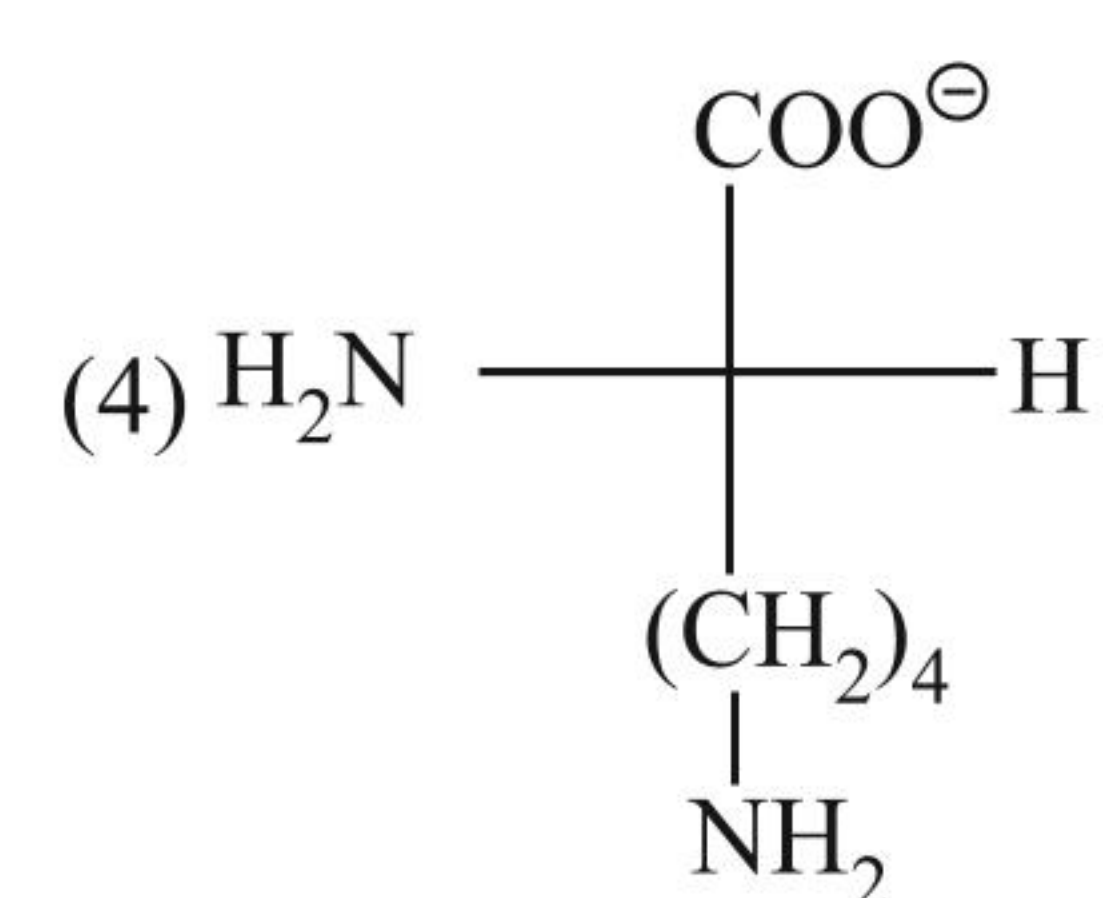
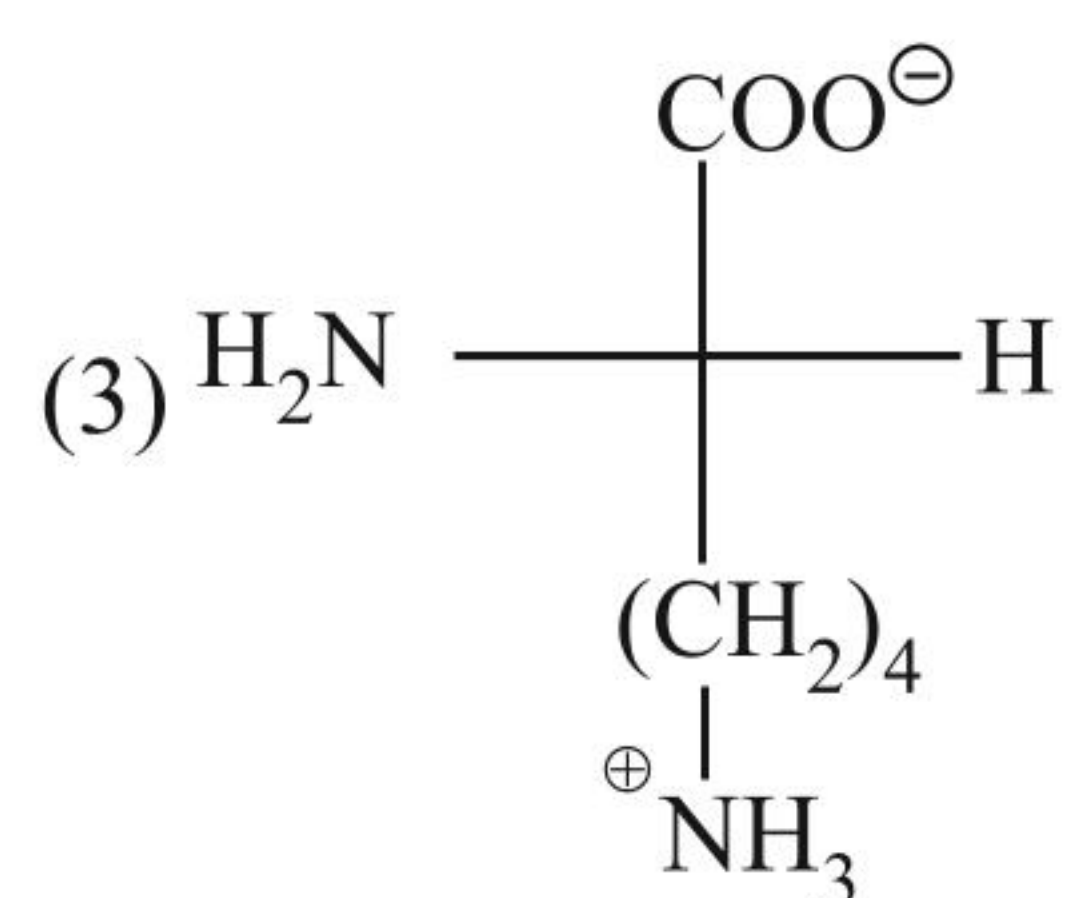
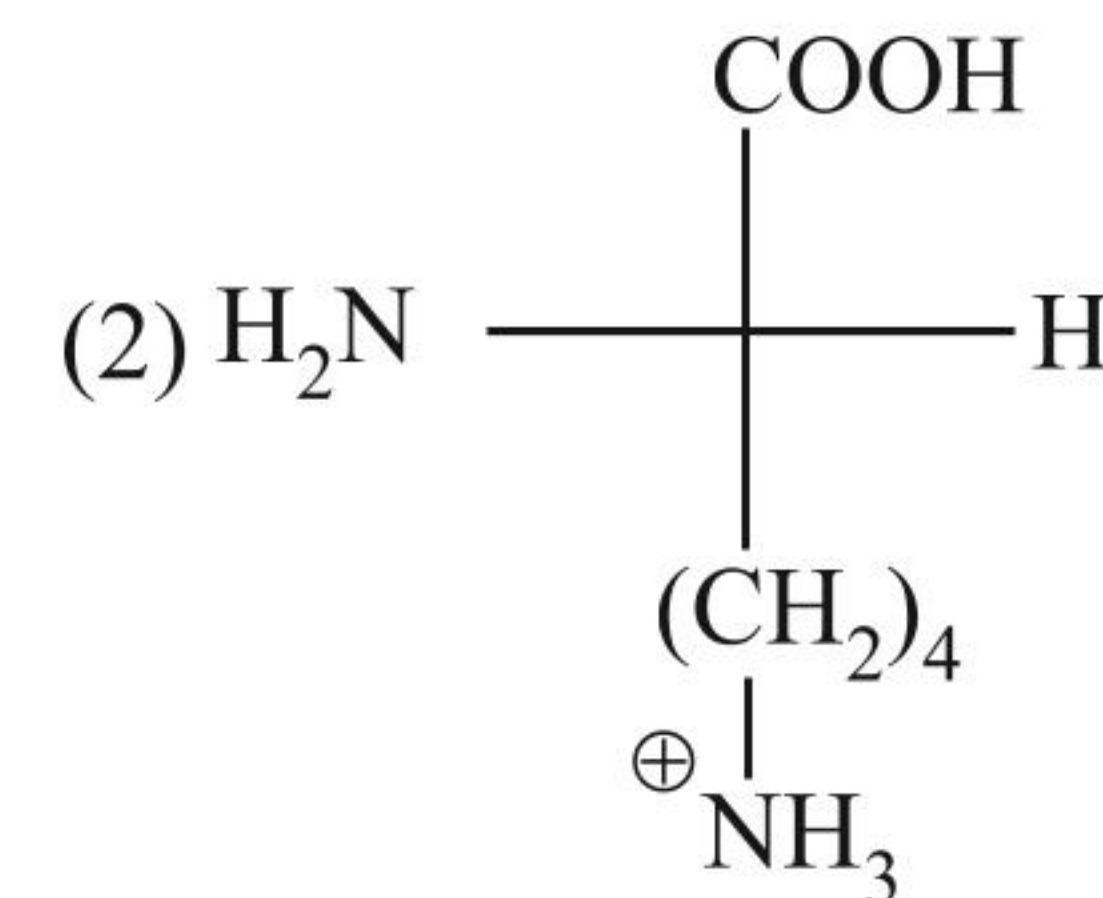
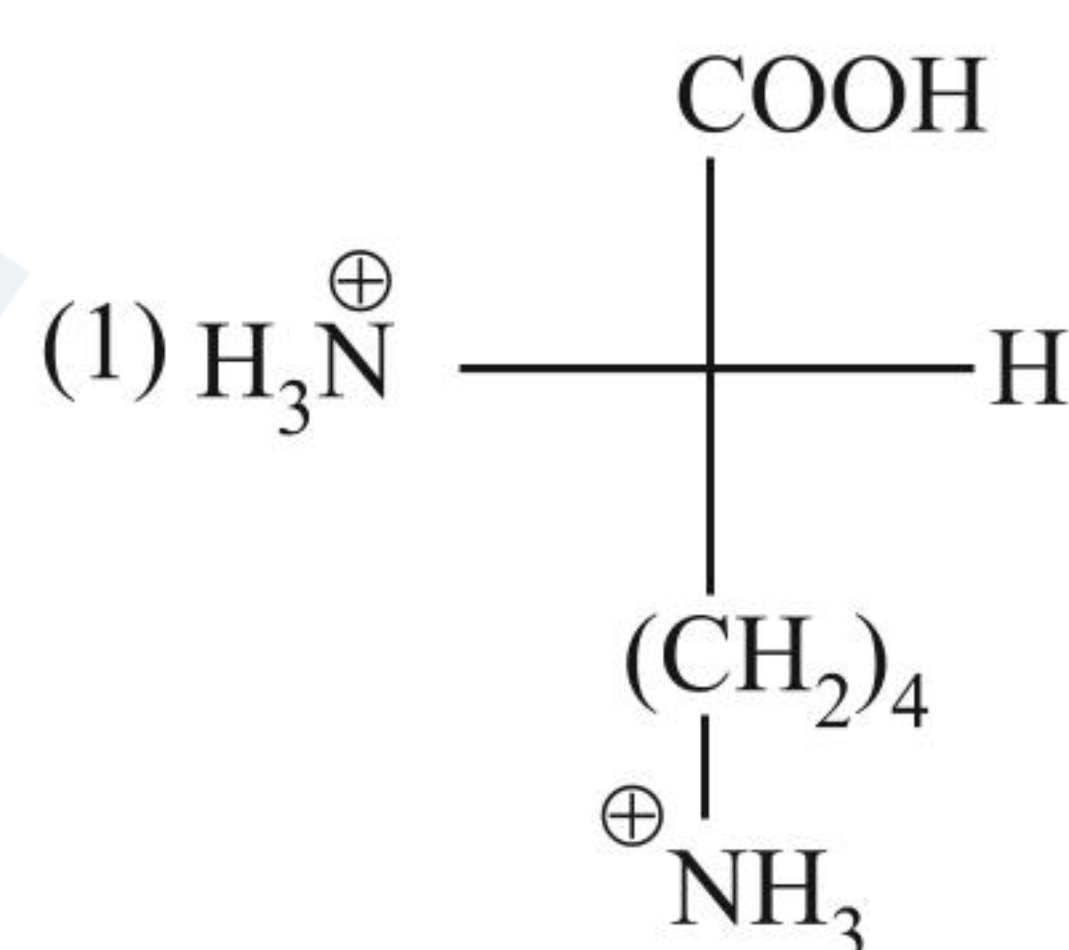
(1) Sugar

(2) Proteins

(3) Fats

(4) Starch

94. Which of the following is the major solute species in a solution of lysine at $\text{pH} = 10.5$?



The order of decreasing acidity of these acidic sites is:

(1) $x > z > y$

(2) $z > x > y$

(3) $x > y > z$

(4) $y > x > z$

96. An amino acid usually shows its lowest solubility in water:

(1) In acidic solution

(2) In basic solution

(3) At pH 7

(4) At isoelectric point

97. Continuous bleeding from an injured part of body is due to deficiency of:

(1) Vitamin A

(2) Vitamin E

(3) Vitamin B

(4) Vitamin K



114. Which statement correctly completes the statement?

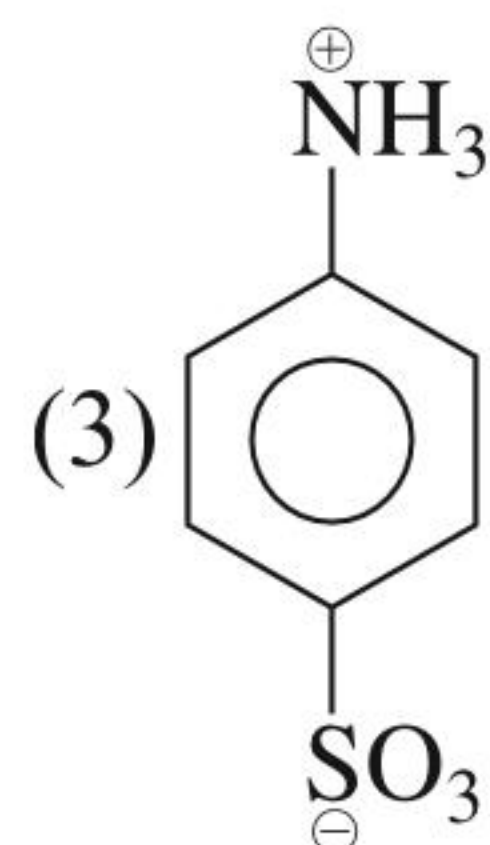
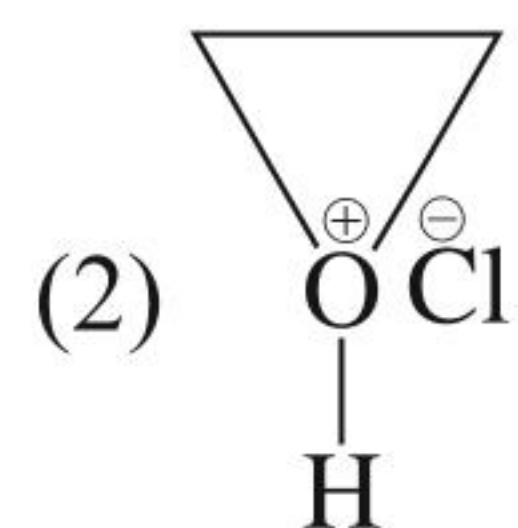
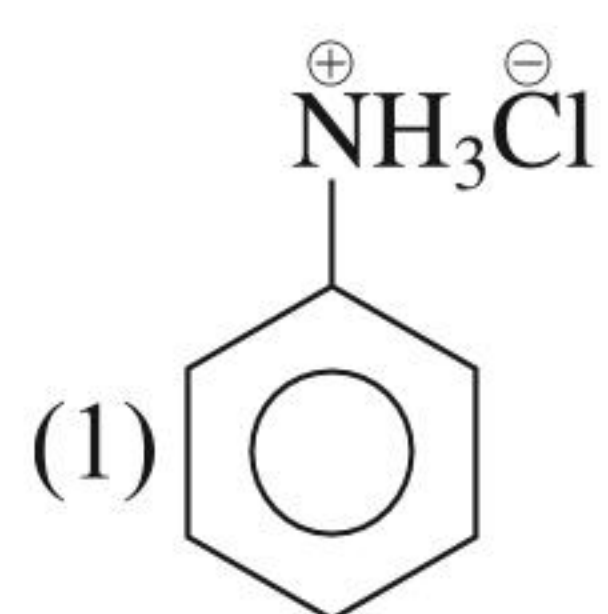
Except for glycine, which is achiral, all the amino acids present in proteins...

- (1) Are chiral, but racemic
- (2) Have the L configuration at their α carbon
- (3) Have the R configuration at their α carbon
- (4) Have the S configuration at their α carbon

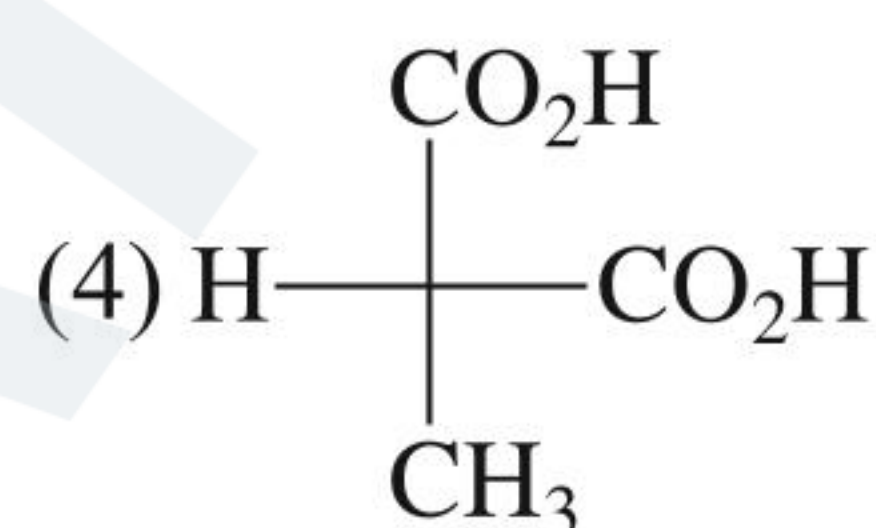
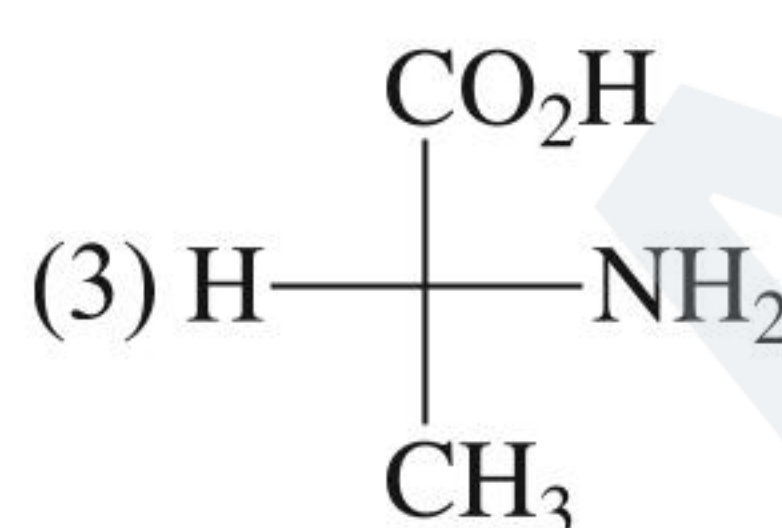
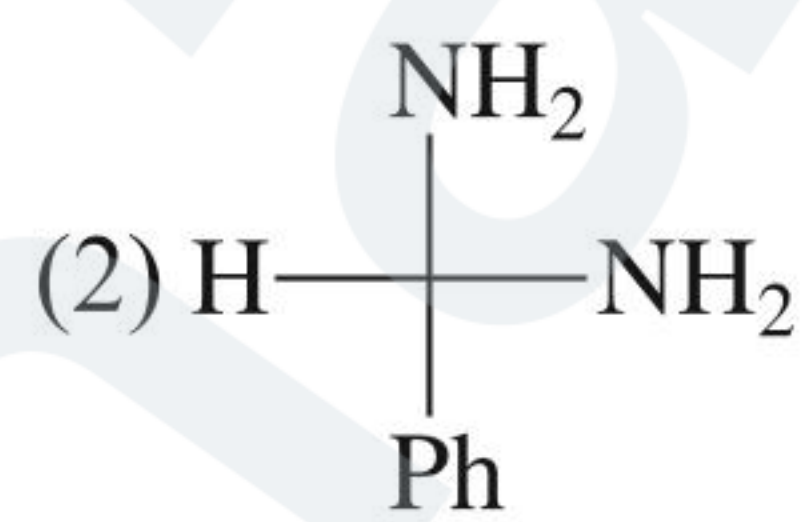
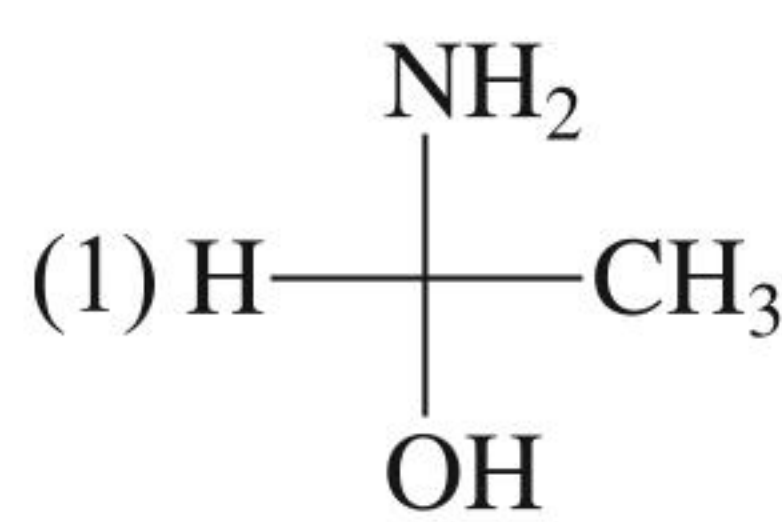
115. Which statement is *incorrect* about peptide bond?

- (1) C—N bond length in proteins is longer than usual bond length of C—N bond
- (2) Spectroscopic analysis shows planar structure of —C(=O)—NH— bond
- (3) C—N bond length in proteins is smaller than usual bond length of C—N bond
- (4) None of these

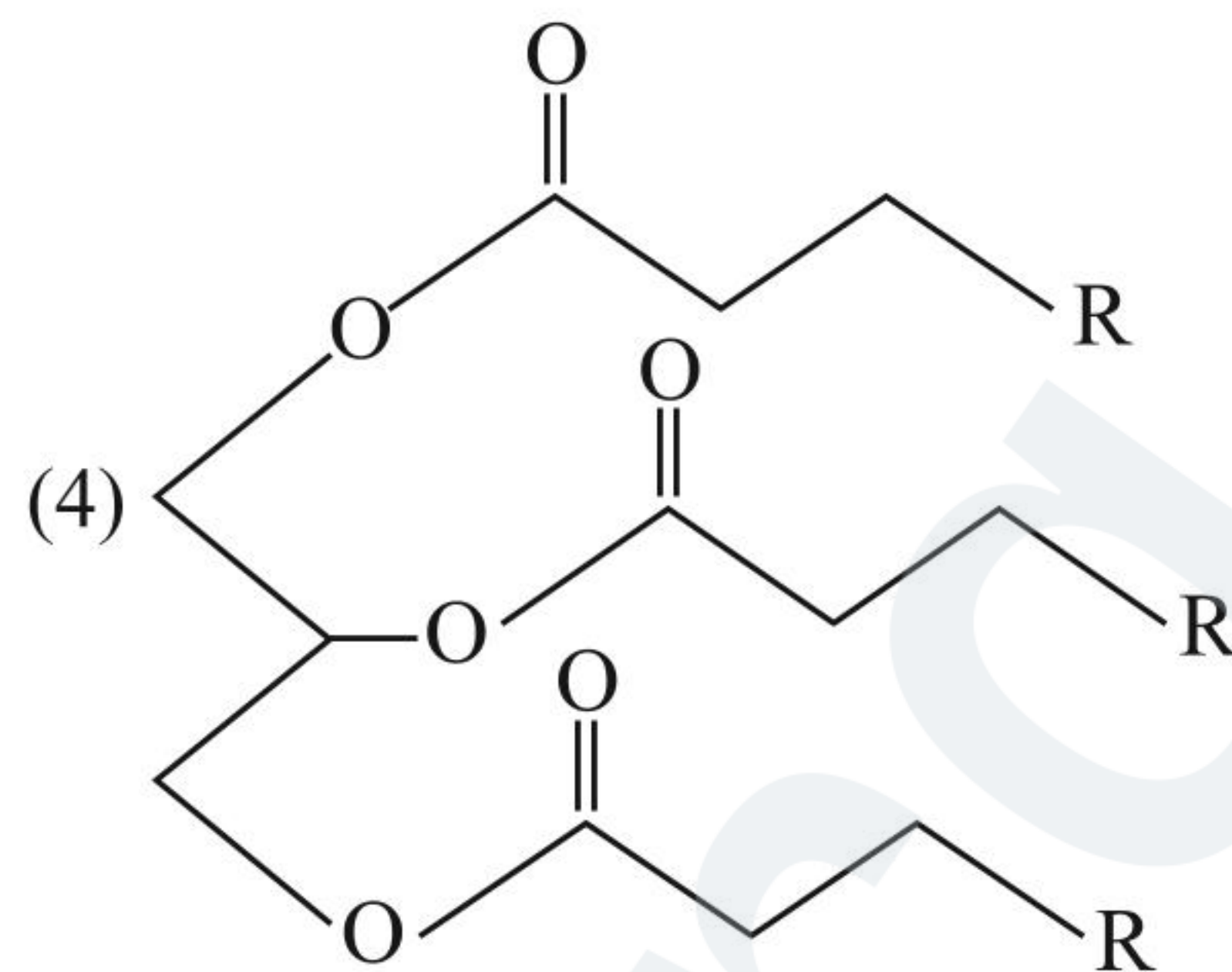
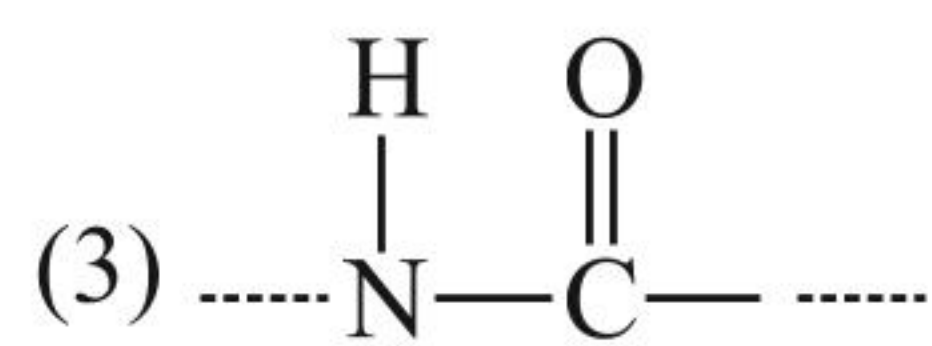
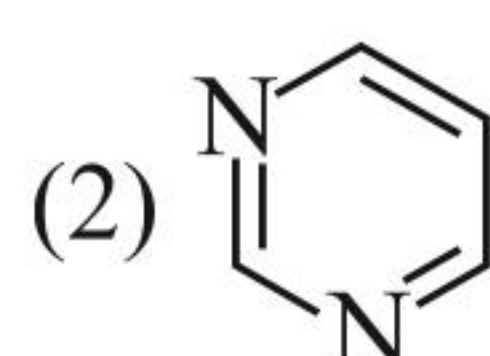
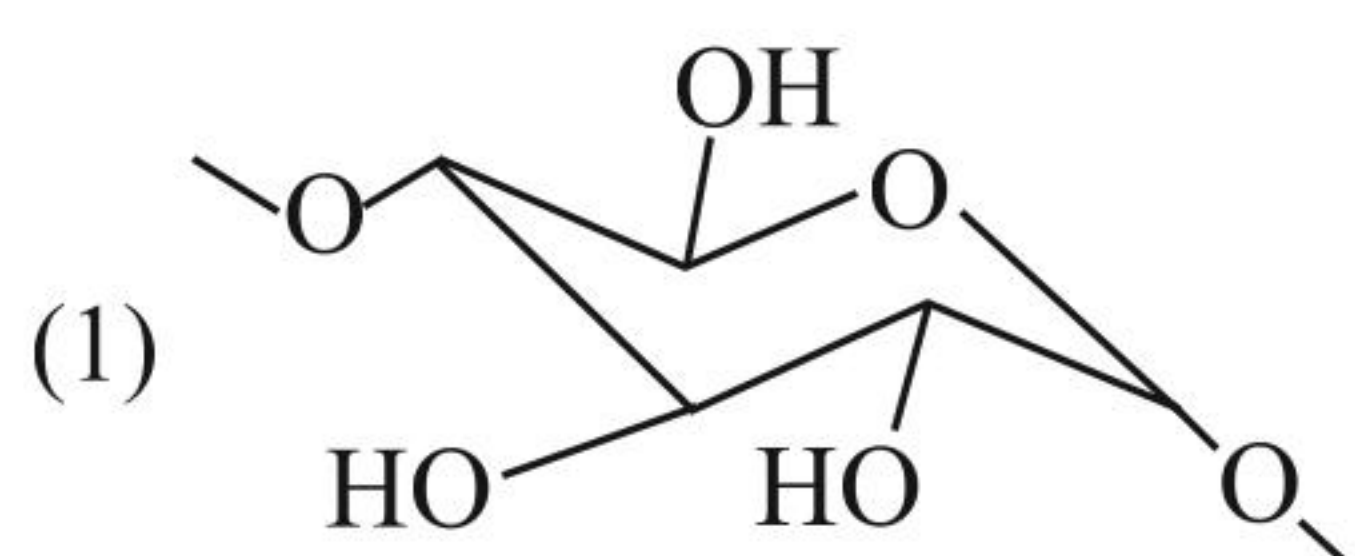
116. Which of the following is Zwitter ion?



117. Which of the following compound can form Zwitter ion?



118. Which of the following chemical units is certainly to be found in an enzyme?



119. The function of enzymes in the living system is to:

- (1) Transport oxygen
- (2) Provide immunity
- (3) Catalyse biochemical reactions
- (4) Provide energy

120. In DNA, the complementary bases are:

- (1) Uracil and adenine: cytosine and guanine
- (2) Adenine and thymine: guanine and cytosine
- (3) Adenine and thymine: guanine and uracil
- (4) Adenine and guanine: thymine and cytosine

121. The hormone which controls the processes of burning of fats, proteins, and carbohydrates and liberates energy in the body is:

- (1) Thyroxine
- (2) Adrenaline
- (3) Insulin
- (4) Cortisone

122. Which of the following has magnesium?

- (1) Chlorophyll
- (2) Haemocyanin
- (3) Carbonic anhydrase
- (4) Vitamin B₁₂

123. Sanger's reagent is used for the identification of:

- (1) N-terminal of a peptide chain
- (2) C-terminal of a peptide chain
- (3) Side chain of amino acids
- (4) Molecular weight of the peptide chain
- (5) Number of amino acids in a peptide chain

124. The number of tripeptides formed by three different amino acids is:

- (1) Three
- (2) Four
- (3) Five
- (4) Six

125. Which structural feature distinguishes proline from other natural α -amino acids?

- (1) It is optically inactive.
- (2) It contains aromatic group.
- (3) It is a dicarboxylic acid.
- (4) It has a secondary amine.
- (5) It contains two amino groups.

126. Which statement is incorrect about the peptide bond?

- (1) (C—N) bond length in proteins is longer than the usual bond length of (C—N) bond.
- (2) Spectroscopic analysis shows planar structure of (CO—NH) group.
- (3) (C—N) bond length in proteins is smaller than usual bond length of (C—N) bond.
- (4) None of the above.

- 127.** The vitamins absorbed from the intestine along with fats are:
 (1) A, D (2) A, B
 (3) A, C (4) D, B
- 128.** The reason for double helical structure of DNA is the operation of:
 (1) Electrostatic attractions
 (2) van der Waals forces
 (3) Dipole–dipole interactions
 (4) Hydrogen bonding
- 129.** Chargaff's rule states that in an organism:
 (1) The amount of adenine (A) is equal to that of thymine (T) and the amount of guanine (G) is equal to that of cytosine (C).
 (2) The amount of adenine (A) is equal to that of guanine (G) and the amount of thymine (T) is equal to that of cytosine (C).
 (3) The amount of adenine (A) is equal to that of cytosine (C) and the amount of thymine (T) is equal to that of guanine (G).
 (4) The amounts of all the bases are equal.
- 130.** Subunits present in haemoglobin are:
 (1) 2 (2) 3
 (3) 4 (4) 5
- 131.** The hormone that helps in the conversion of glucose into glycogen is:
 (1) Cortisone (2) Bile acids
 (3) Adrenaline (4) Insulin
- 132.** The correct statement in respect of protein haemoglobin is that it
 (1) functions as a catalyst for biological reactions.
 (2) maintains blood sugar level.
 (3) acts as an oxygen carrier in the blood.
 (4) forms antibodies and offers resistance to diseases.
- 133.** The helical structure of protein is stabilised by:
 (1) Dipeptide bonds (2) Hydrogen bonds
 (3) Ether bonds (4) Peptide bonds
- 134.** Insulin production and its action in human body are responsible for the level of diabetes. This compound belongs to which of the following categories:
 (1) A coenzyme (2) A hormone
 (3) An enzyme (4) An antibiotic
- 135.** The nucleic acid base having two possible binding sites is:
 (1) Thymine (2) Cytosine
 (3) Guanine (4) Adenine
- 136.** An alteration in the base sequence of nucleic acid molecule is:
 (1) Replication (2) Mutation
 (3) Duplication (4) Dislocation
 (5) Flocculation
- 137.** Which functional group participates in the disulphide bond formation in proteins?
 (1) Thioether (2) Thiol
 (3) Thioester (4) Thiolactone
- 138.** In both DNA and RNA, the heterocyclic base and phosphate ester linkages are at:
 (1) C₅ and C₂, respectively, of the sugar molecule.
 (2) C₂ and C₅, respectively, of the sugar molecule.
 (3) C₁ and C₅, respectively, of the sugar molecule.
 (4) C₅ and C₁, respectively, of the sugar molecule.
- 139.** Which of the following statements is true for protein synthesis (translation)?
 (1) Amino acids are directly recognised by *m*-RNA.
 (2) The third base of the codon is less specific.
 (3) Only one codon codes for an amino acid.
 (4) Every *t*-RNA has more than one amino acid attachment.
- 140.** The human body does not produce:
 (1) Enzymes (2) DNA
 (3) Vitamins (4) Hormones
- 141.** During the process of digestion, the proteins present in food materials are hydrolysed to amino acids. The two enzymes involved in the process are:

$$\text{Proteins} \xrightarrow{\text{Enzyme (A)}} \text{Polypeptides}$$

$$\xrightarrow{\text{Enzyme (B)}} \text{Amino acids}$$
- (1) Invertase and zymase (2) Amylase and maltase
 (3) Diastase and lipase (4) Pepsin and trypsin
- 142.** The pair in which both the species have iron is:
 (1) Nitrogenase, cytochromes
 (2) Carboxypeptidase, haemoglobin
 (3) Haemocyanin, nitrogenase
 (4) Haemoglobin, cytochromes
- 143.** At pH = 4, glycine exists as:
 (1) $\text{H}_3\text{N}^{\oplus} - \text{CH}_2\text{COO}^{\ominus}$ (2) $\text{H}_3\text{N}^{\oplus} - \text{CH}_2\text{COOH}$
 (3) $\text{H}_2\text{NCH}_2\text{COOH}$ (4) $\text{H}_2\text{NCH}_2\text{COO}^{\ominus}$
- 144.** Biotin is an organic compound present in yeast. Its deficiency in diet causes dermatitis and paralysis. It is also known as:
 (1) Vitamin H (2) Vitamin B₁
 (3) Vitamin B₁₂ (4) Vitamin D
- 145.** The efficiency of an enzyme to catalyse a reaction is due to its capacity to:
 (1) Reduce the activation energy of the reaction.
 (2) Form strong enzyme–substrate complex.
 (3) Decrease the bond energies of all the substrate molecules.
 (4) Increase the free energy of the catalyst–substrate reaction.
 (5) Alter the substrate geometry to fit into the shape of the enzyme molecule.

146. The α -amino acid which contains the aromatic side chain is:

- (1) Proline (2) Tyrosine
(3) Valine (4) Tryptophan

147. Check the incorrect statement.

- (1) Proteins, like fats and carbohydrates, are primarily used for supplying heat and energy to the body.
(2) Proteins differ from fats and carbohydrates in that they contain nitrogen.
(3) Amino acids in proteins have L-configuration.
(4) Enzymes are proteins.

148. Check the incorrect statement.

- (1) Adenine and guanine are both purine bases and are found both in DNA and RNA.
(2) Genetic information is based upon the nucleotide sequence in DNA.
(3) The genetic code consists of triplets of nucleotide; each triplet codes an amino acid.
(4) Transfer RNA carries the code for the synthesis of proteins.

149. Which of the following statements is incorrect?

- (1) Vitamins are included in diet because they are not synthesised in the human body.
(2) Most vitamins function as coenzymes.
(3) A person with diabetes mellitus suffers from hypoglycemia.
(4) Hypoglycemia can affect the brain due to low blood sugar level.

150. During aerobic respiration, one molecule of glucose produces:

- (1) 2 ATP molecules (2) 50 ATP molecules
(3) 38 ATP molecules (4) 36 ATP molecules

151. The chemical substance which acts as emulsifier is:

- (1) Phosphoric acid (2) Fatty acid
(3) Bile acids (4) Mineral acids (HCl)

152. If the sequence of bases in one strand of DNA is ATGACTGTC then the sequence of bases in its complementary strand is:

- (1) TACTGACAG (2) TUCTGUCCUG
(3) GUAGTUAUG (4) None of the above

153. The RNA which takes part in the synthesis of proteins is:

- (1) *m*-RNA (2) *r*-RNA
(3) *t*-RNA (4) All the above

154. Mark the incorrect statement about ATP.

- (1) It is a nucleotide.
(2) It contains the purine adenine.
(3) The enzyme-catalysed hydrolysis of ATP to ADP and AMP is accompanied by absorption of energy.
(4) Energy is stored in the cell in the form of ATP.

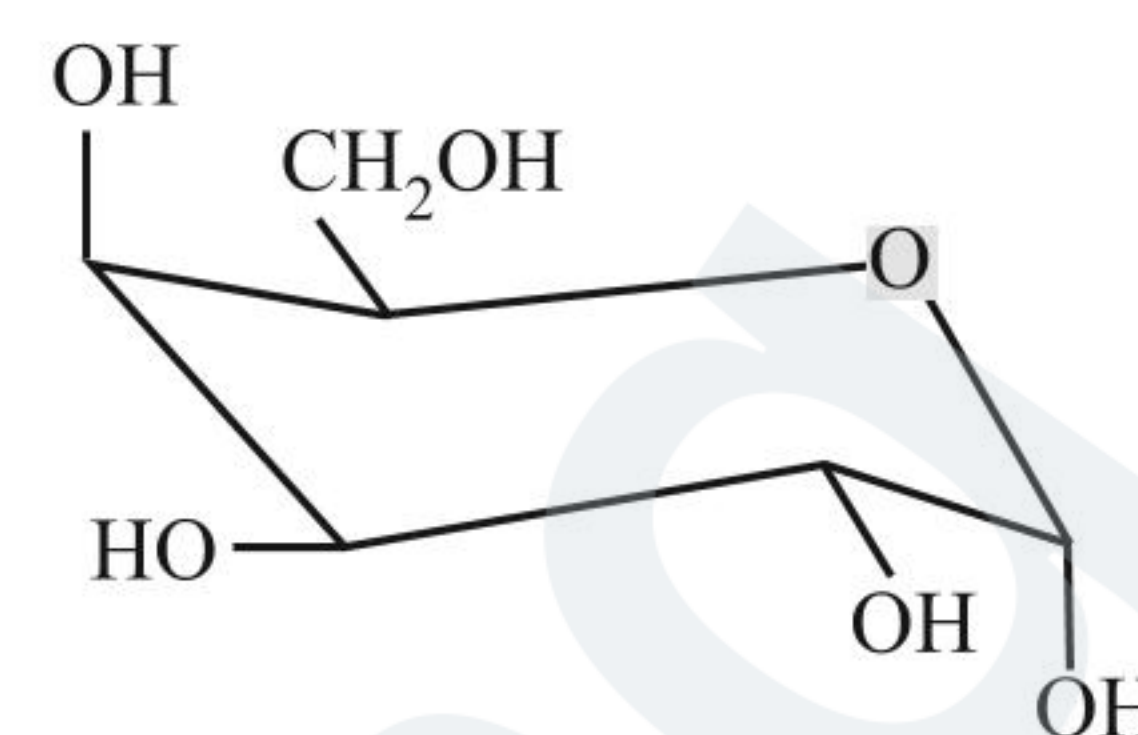
155. The sequence in which amino acids are linked to one another in a protein molecule is called its:

- (1) Primary structure (2) Secondary structure
(3) Tertiary structure (4) Quaternary structure

Multiple Correct Answers Type

Preparation and Properties of Monosaccharides

1. The correct statement(s) for compound is/are:

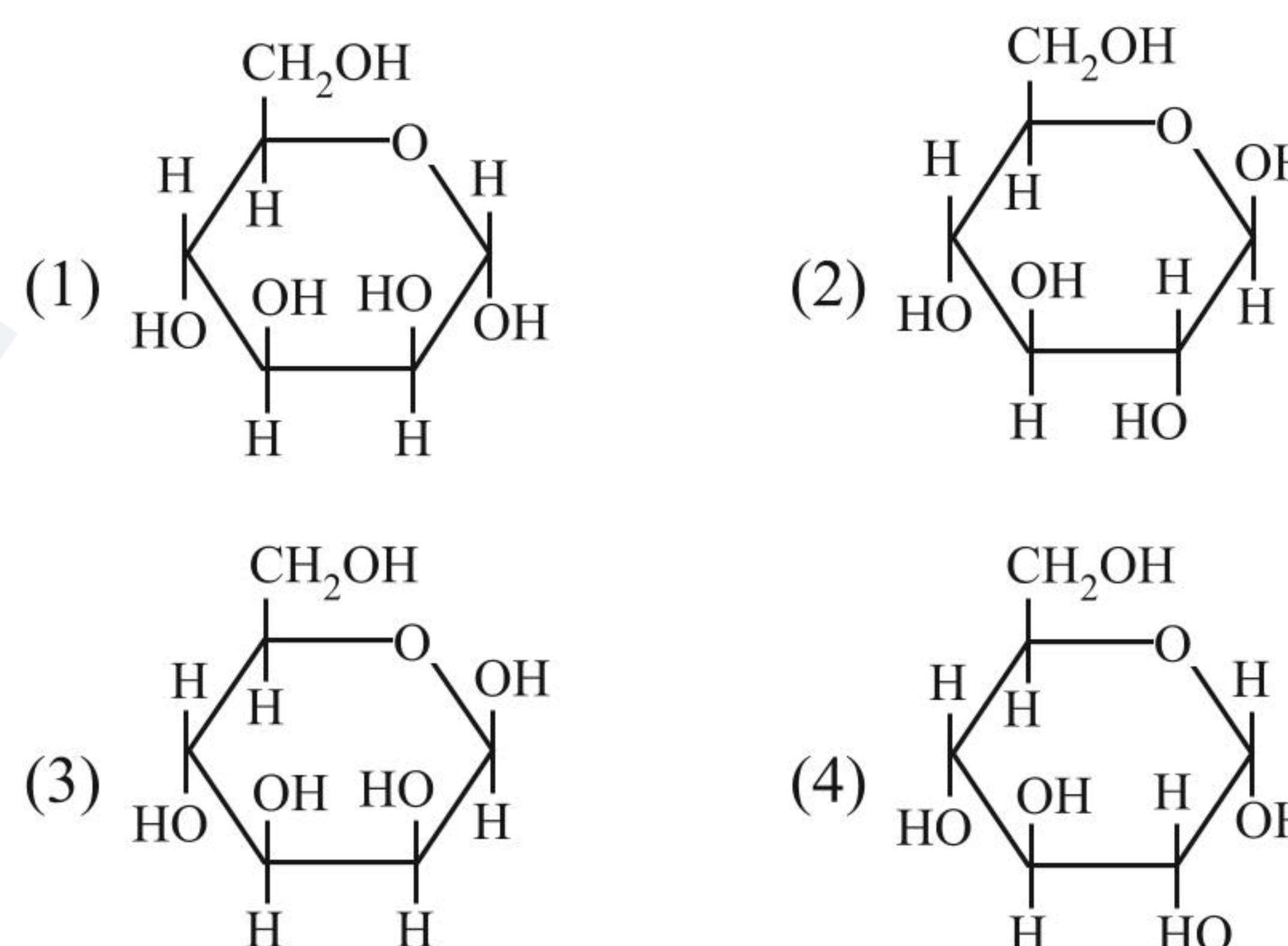


- (1) Aldohexose (2) Pyranose form
(3) C₄-epimer of glucose (4) Non-reducing sugar

2. Which of the following statements are correct?

- (1) Monosaccharides are optically active polyhydroxy carbonyl compounds.
(2) Fructose does not react with Fehling's solution because it is keto.
(3) α -D-Glucose and β -D-Glucose are anomers.
(4) D-Glucose and D-Mannose are epimers.

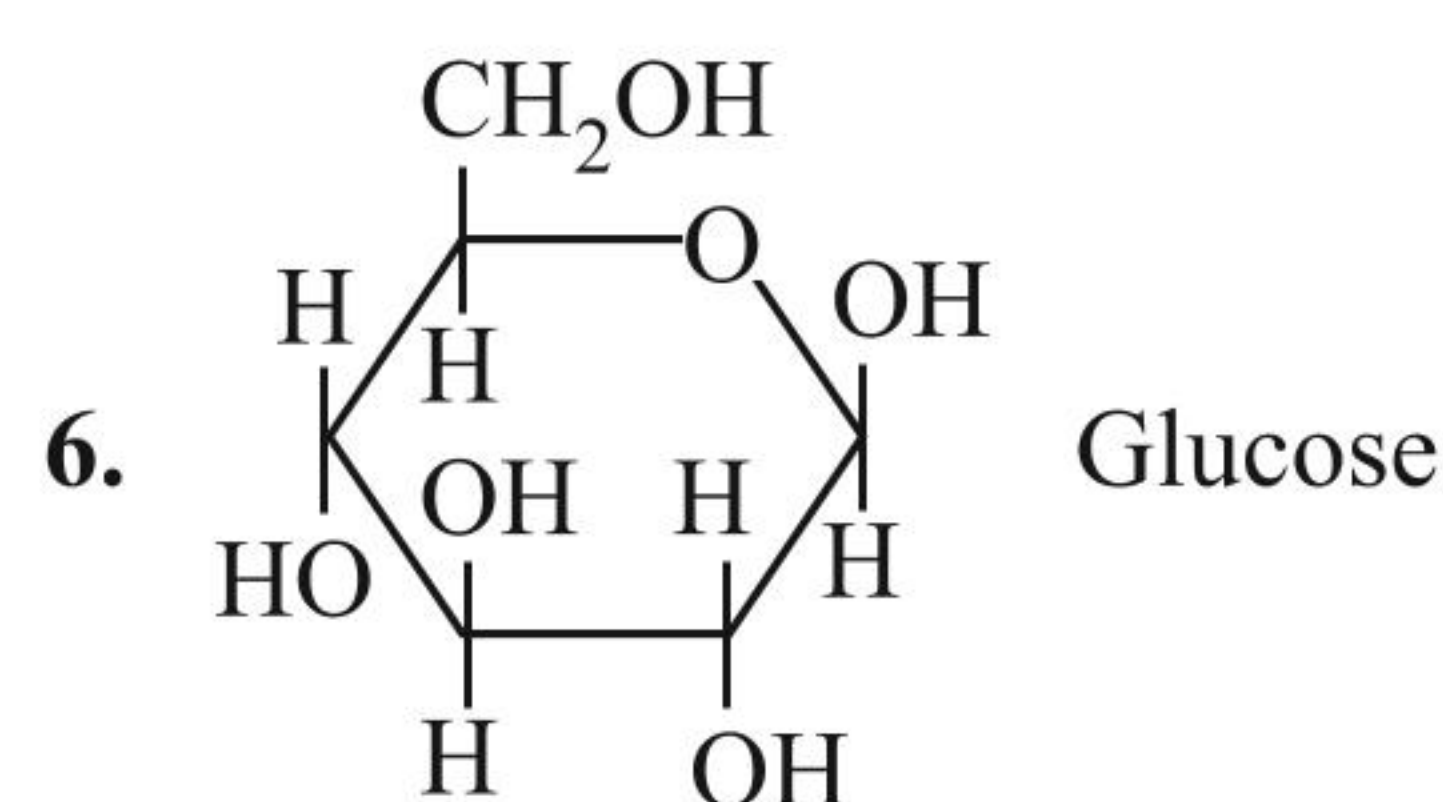
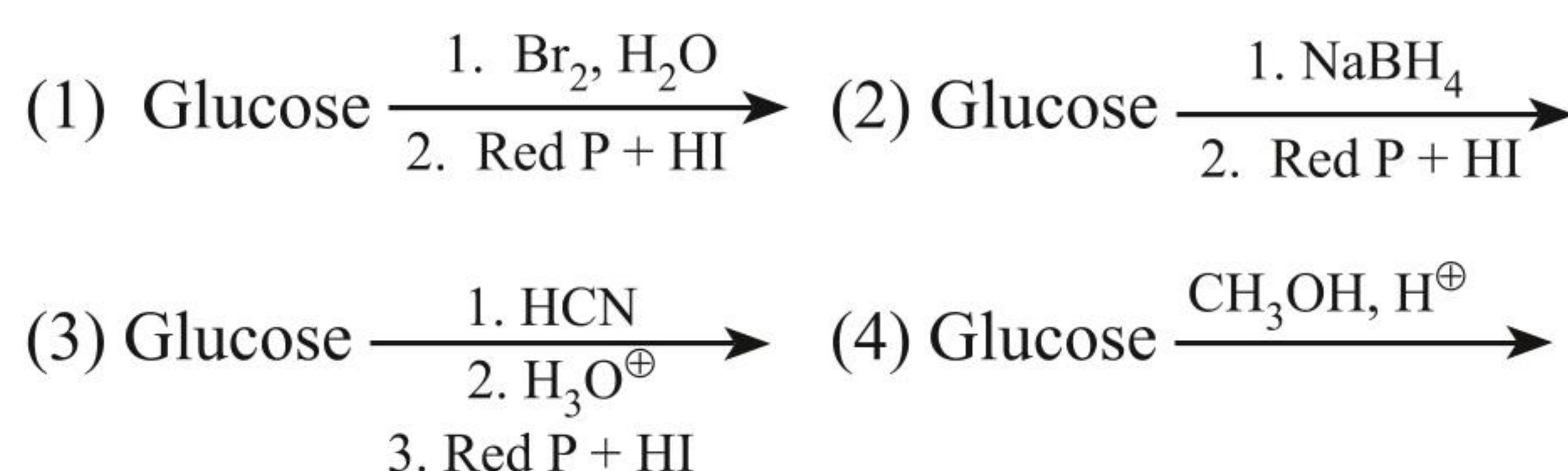
3. D-Mannose differs from D-glucose in its stereochemistry at C-2. The pyranose form of D-Mannose is:



4. Which of the following reagents would convert an aldose into corresponding aldonic acid?

- (1) Tollen's reagent (2) Fehling's solution
(3) Bromine water (4) Red P + HI

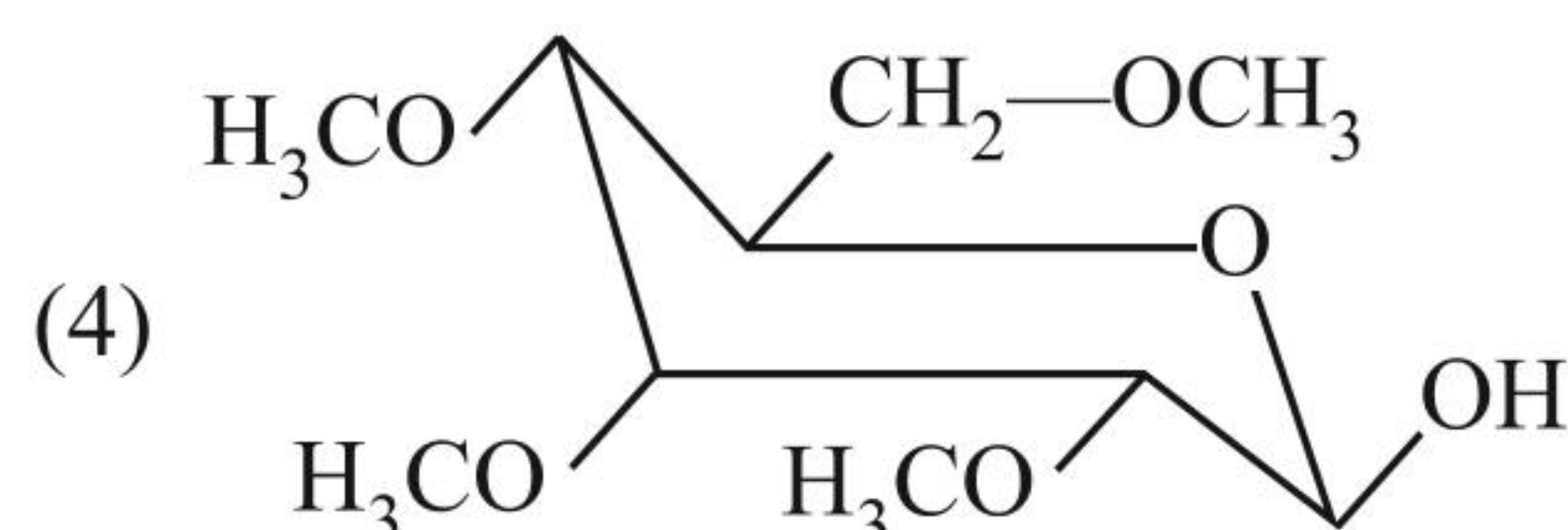
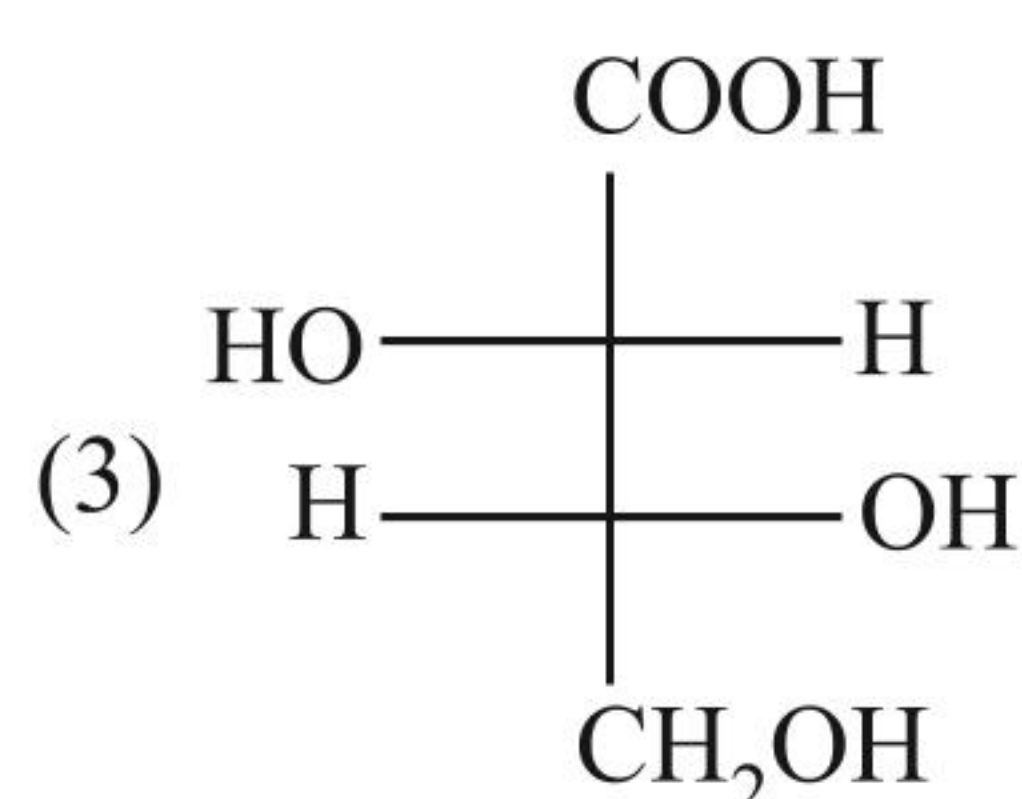
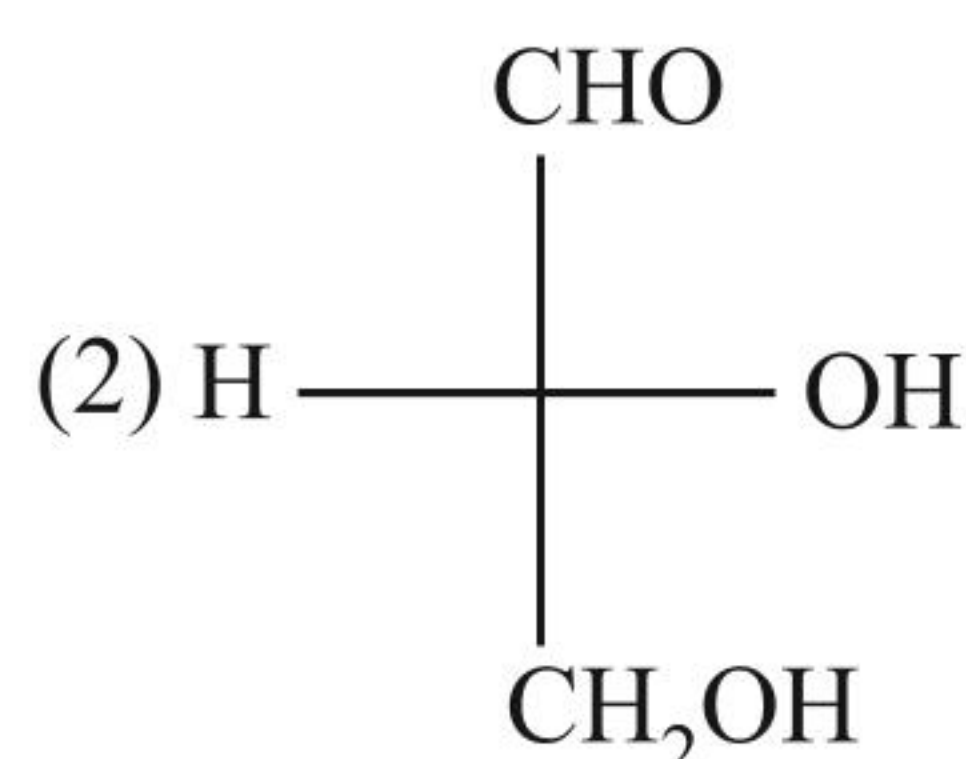
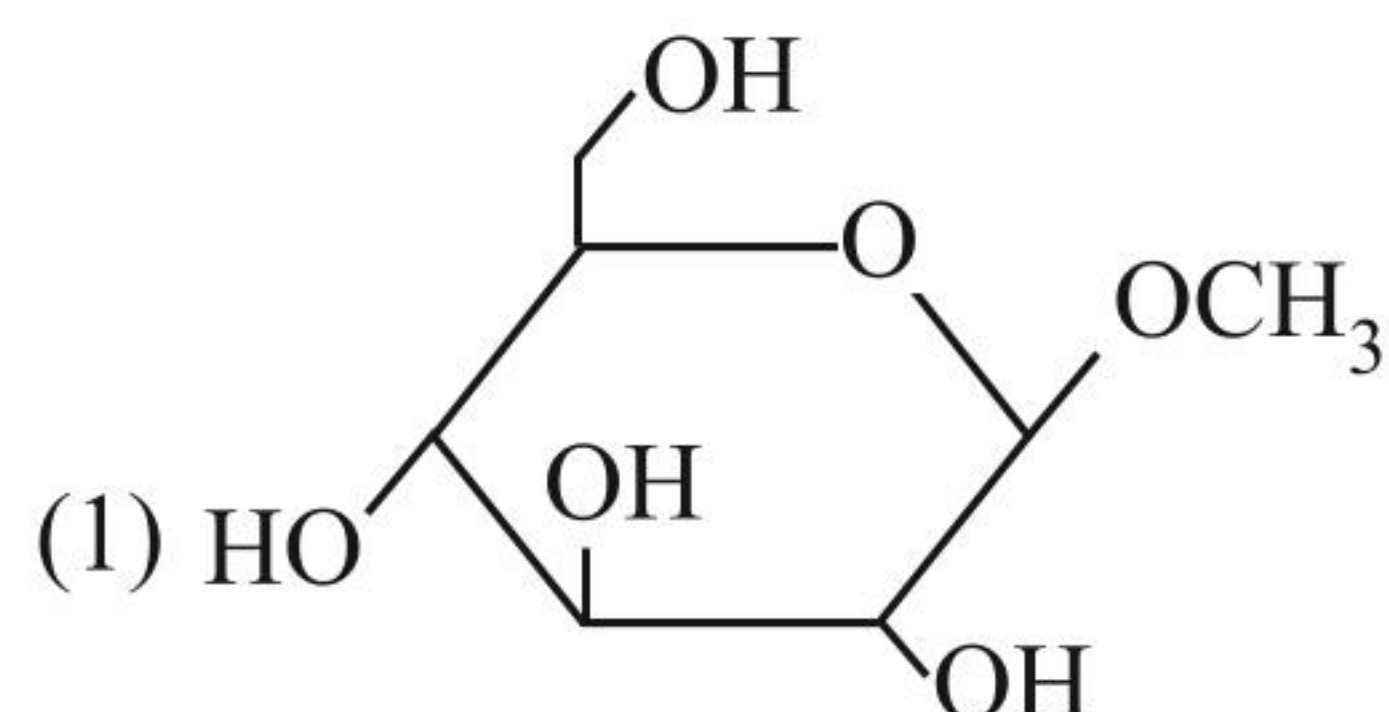
5. The final product of which of the following reactions furnishes evidence that glucose has unbranched carbon chain:



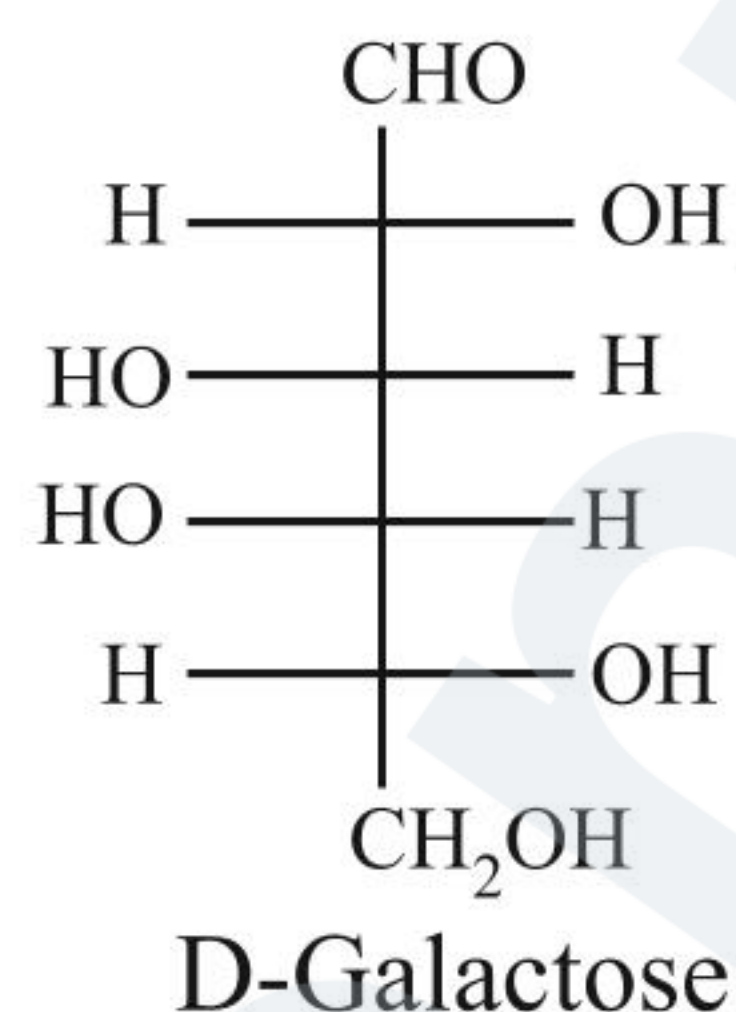
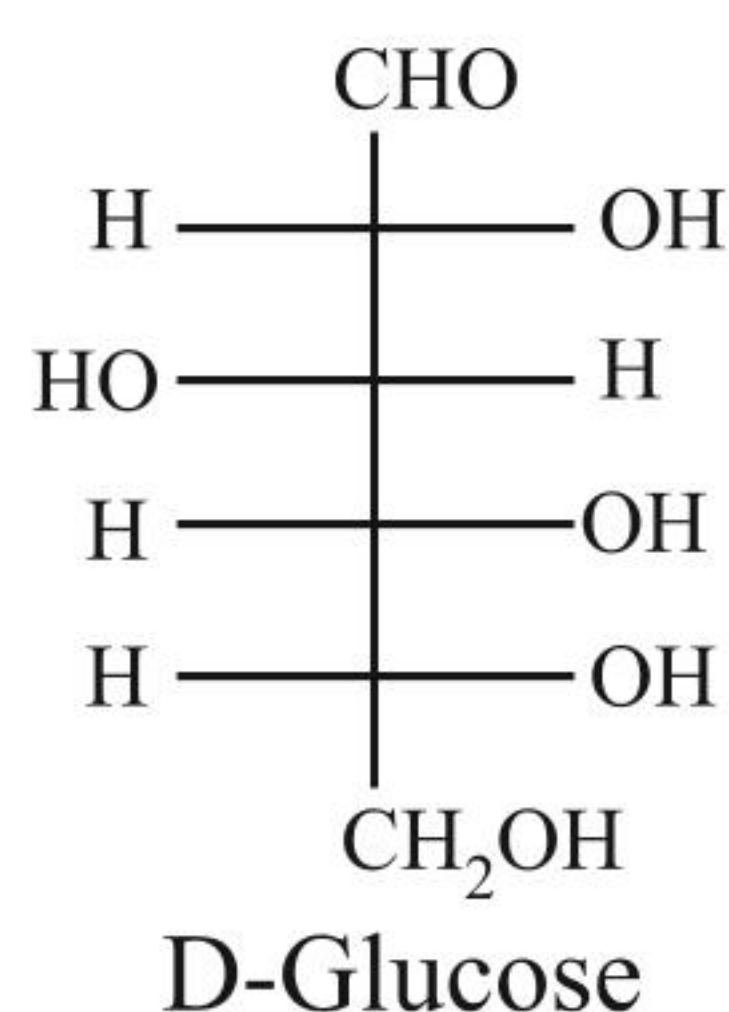
The **correct** statements about above structure of glucose are:

- (1) It is a pyranose form (2) It is a furanose form
(3) It is a β -anomer (4) It is a D-sugar

7. Which of the following carbohydrate are D-isomers ?



8. Following are the structure of D-Glucose and D-Galactose.



Which of the following statements are **correct** about these compounds ?

- (1) They are diastereomers.
(2) Both are component of lactose.
(3) They are C_4 epimer.
(4) Both are optically active.

9. When D-Glucose is treated with base it is converted into:

- (1) D-Fructose (2) D-Mannose
(3) D-Glucose (4) D-Arabinose

10. When fructose treated with Tollen's reagent, silver mirror is formed due to reduction of Ag^+ by:

- (1) Fructose itself
(2) Glucose formed by isomerisation
(3) Mannose formed by isomerisation
(4) Galactose formed by isomerisation

11. Find the **correct** statements regarding the methyl glucosides obtained by the reaction of D-Glucose with methanol in presence of dry HCl gas.

- (1) These are methyl ether of hemiacetal of glucose formed by intramolecular reaction.
(2) These are enantiomers.
(3) These are anomers.
(4) In one of these all the substituents are equatorial.

12. Which of the following statements are correct for glucose?

- (1) It gives positive test with Schiff's reagent.
(2) It reacts with $NaHSO_3$ and NH_3 .
(3) Pentaacetate derivative of glucose does not react with H_2N-OH .
(4) It gives positive test with Fehling's solution.

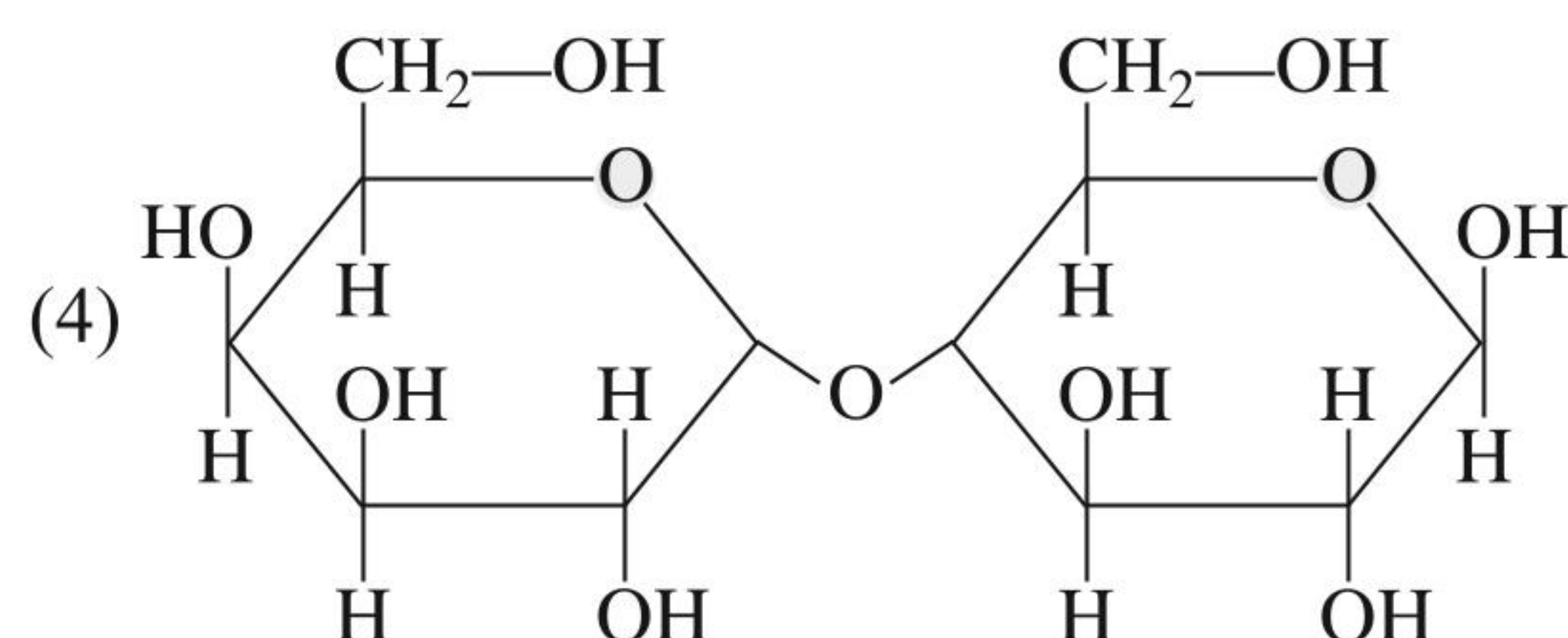
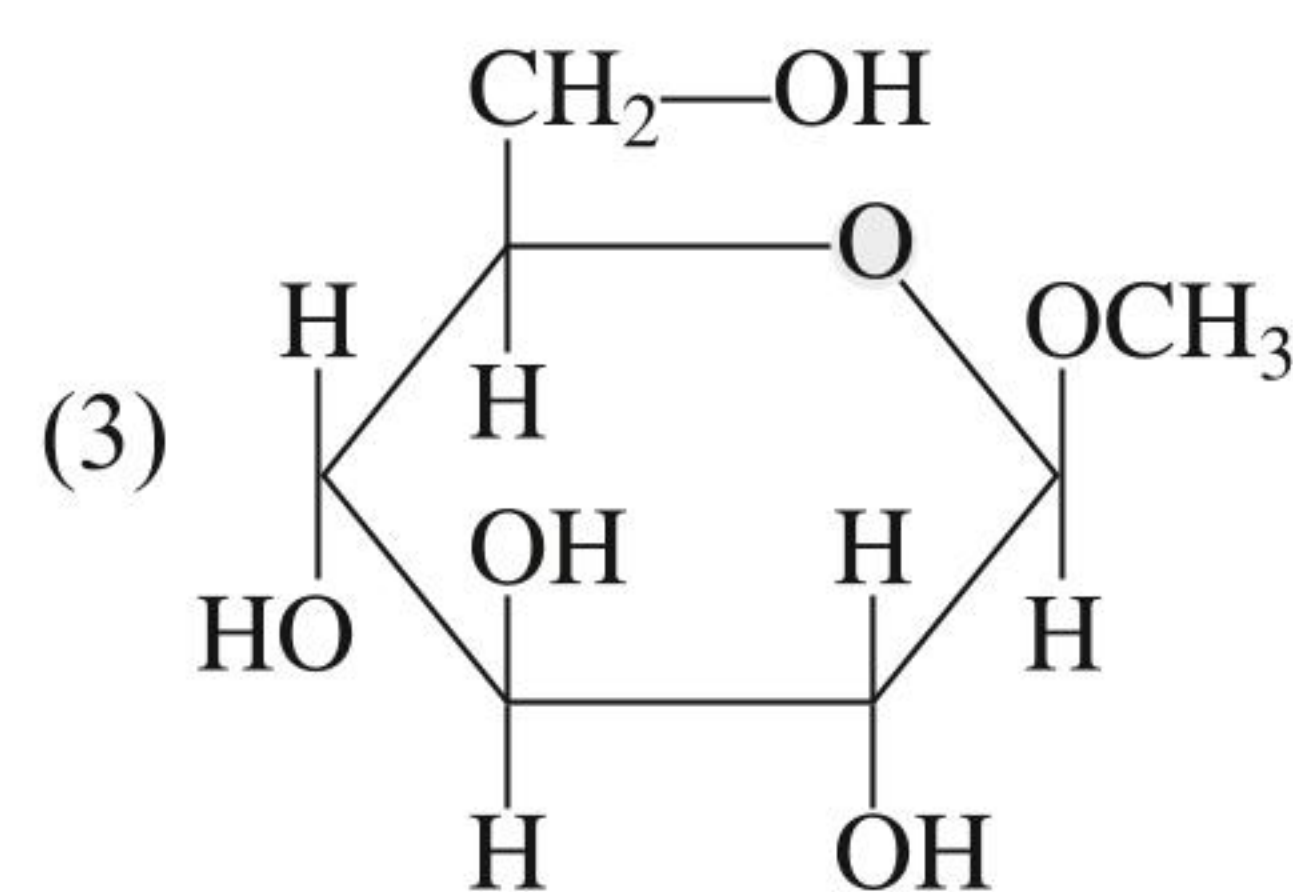
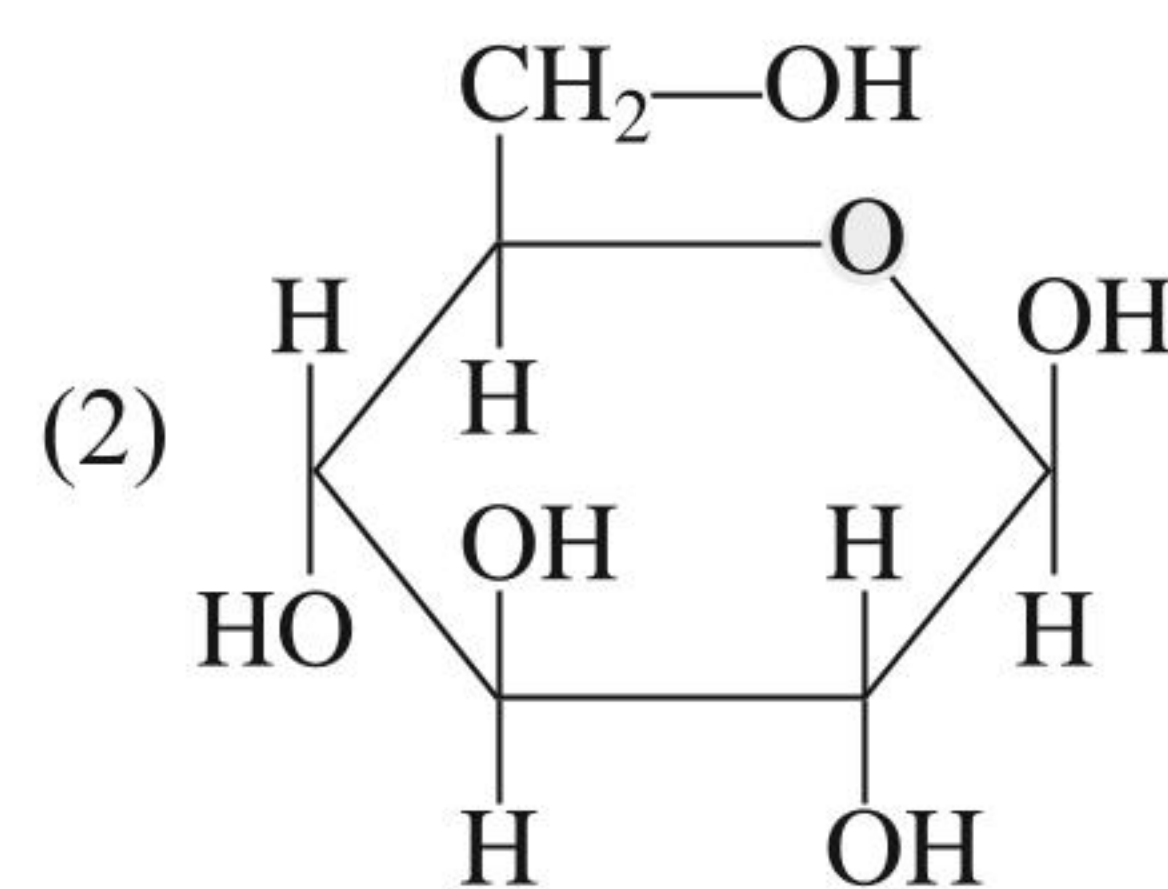
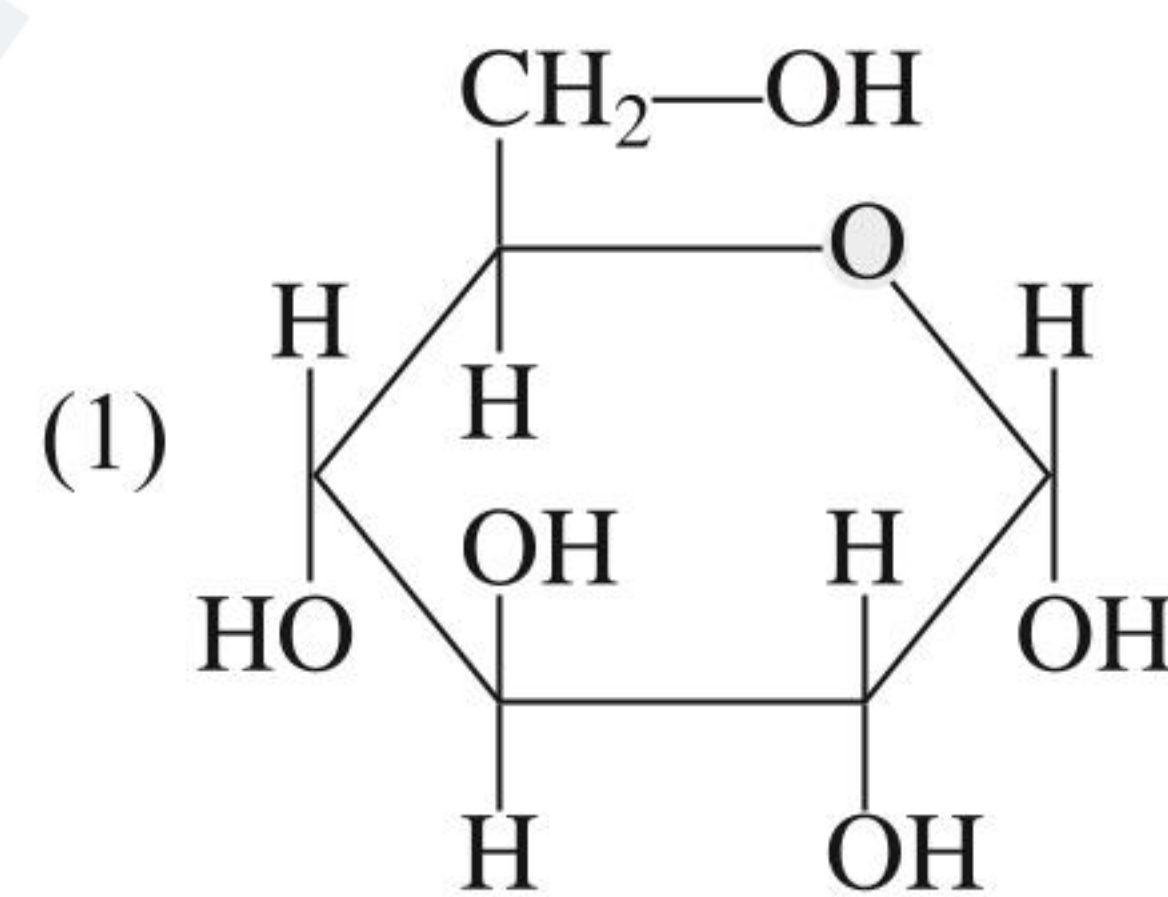
13. The presence of $-CHO$ group in glucose is confirmed by its:

- (1) Reaction with PCl_5 .
(2) Reaction by $Na-Hg$ to give α -sorbitol.
(3) Reaction with Fehling solution
(4) Reaction with Tollen's reagent

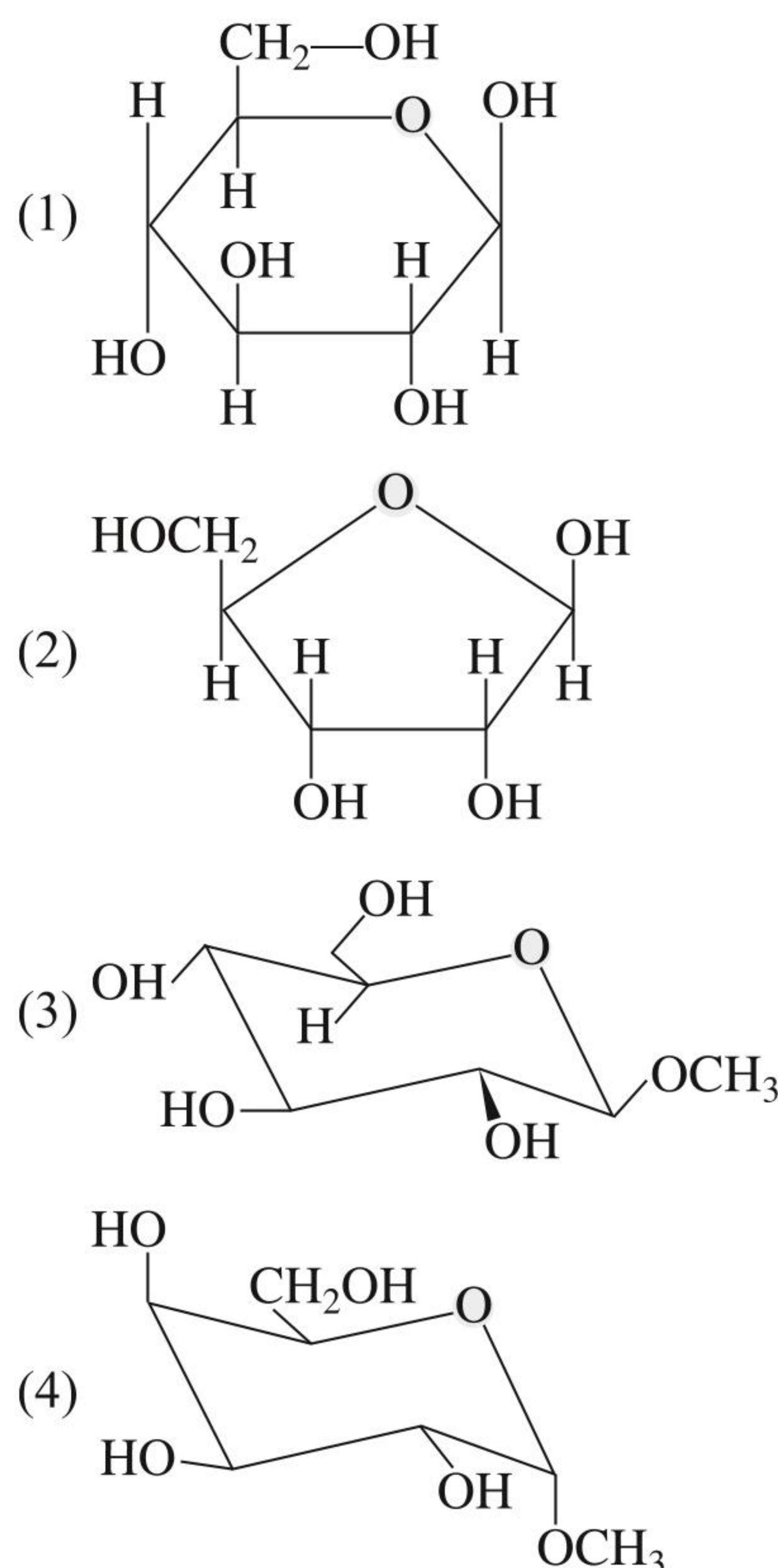
14. Which of the following pairs forms the same osazone with phenylhydrazine?

- (1) D-Glucose and D-Fructose
(2) D-Fructose and D-Mannose
(3) D-Glucose and D-Mannose
(4) D-Glucose and D-Galactose

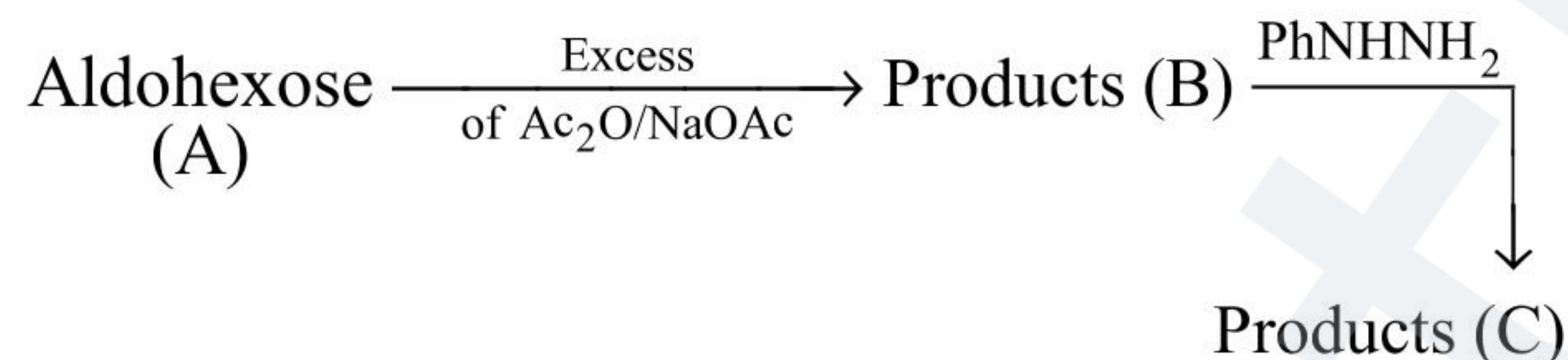
15. Which of the following is reducing sugar?



16. Which of the following compound will show mutarotation?

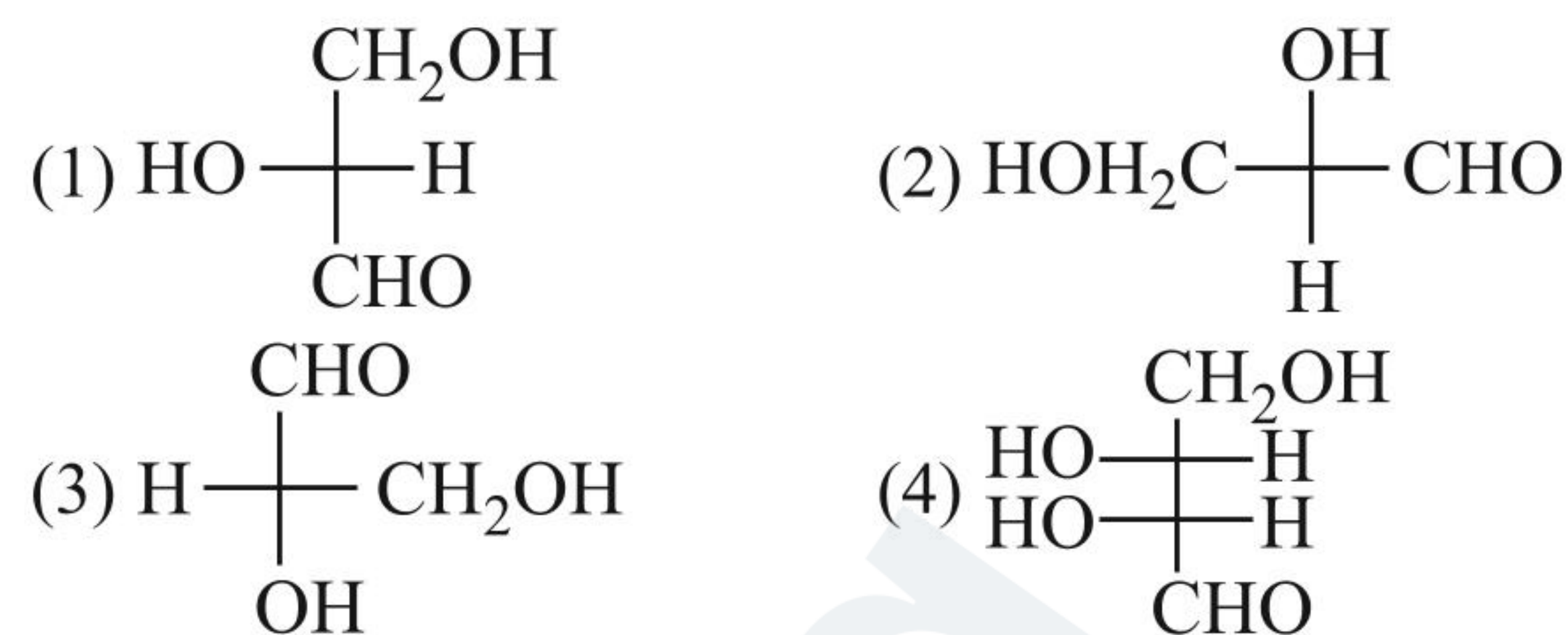


17. Which statements are correct about the reaction?



- (1) Products (B) are α - and β -penta acetates.
 (2) Products (B) are α - and β -tetra acetates.
 (3) Products (C) are phenyl hydrazones of products (B).
 (4) Products (B) do not react with PhNHNH_2 .
18. Which of the statements are correct?
 (1) Aldoses react with Benedict's solution and PhNHNH_2 .
 (2) Aldoses do not react with NaHSO_3 .
 (3) Ketoses react with Fehling's solution and PhNHNH_2 .
 (4) Ketoses react with NaHSO_3 .
19. Which statements are correct about the reactions?
 $\text{D-Glucose} \xrightarrow{\text{NaCN/HCN}} \text{Products.}$
 (1) The C chain is increased by one C atom.
 (2) Two isomeric products, cyanohydrin and its C-2 epimeric cyanohydrin are formed.
 (3) Epimers formed in products are in unequal amounts.
 (4) The presence of stereocentres in sugars causes their (C = O) groups to have diastereotopic faces that react at different rates, giving different amounts of diastereomers.

20. Which of the following are D-sugars?



21. Which of the following pairs are C-2 epimers?
 (1) Allose, Altrose (2) Glucose, Mannose
 (3) Gulose, Indose (4) Galactose, Talose
22. Which of the following pairs form same osazone?
 (1) Glucose, Fructose (2) Glucose, Mannose
 (3) Ribose, Arabinose (4) Mannose, Fructose
23. Which of the following pairs are C-2 epimers as well as enantiomers?
 (1) D-Glyceraldehyde and L-Glyceraldehyde
 (2) D-Erythrose and D-Threose
 (3) D-Ribose and D-Arabinose
 (4) D-Xylose and D-Lyxose
24. The smallest aldose which is able to form cyclic hemiacetal is/are:
 (1) D-glyceraldehyde (2) D-Erythrose
 (3) D-Threose (4) D-Ribose
25. Which of the following statements are correct?
 (1) D-Mannose is a C-2 epimer of D-glucose.
 (2) D-Allose is a C-3 epimer of D-glucose.
 (3) D-Galactose is a C-4 epimer of D-glucose.
 (4) α -D (+) glucopyranose and β -D (+) glucofuranose are anomers.
26. Which of the following statements are correct?
 (1) One mole of PhNHNH_2 reacts with 3 mol glucose to form osazone.
 (2) One mole of D-fructose reacts with 3 mol PhNHNH_2 to form osazone.
 (3) One mole of D-2-deoxy glucose reacts with 1 mol PhNHNH_2 to form phenylhydrazone.
 (4) One mole of D-3-deoxy glucose reacts with 3 mol of PhNHNH_2 to form osazone.
27. Which of the following exhibit mutarotation?
 (1) Glucose (2) Maltose
 (3) Fructose (4) Galactose
28. Which of the following statements are correct?
 (1) β -D (+) glucopyranose is more stable than α -D (+) glucopyranose.
 (2) Invert sugar is laevorotatory.
 (3) Dextrose is D (+) glucose.
 (4) Levulose is D (-) fructose.
29. Which of the following statements are false?
 (1) Glucose is the only aldose that mutarotates.
 (2) Ketose also mutarotates.
 (3) Glycosides mutarotate.

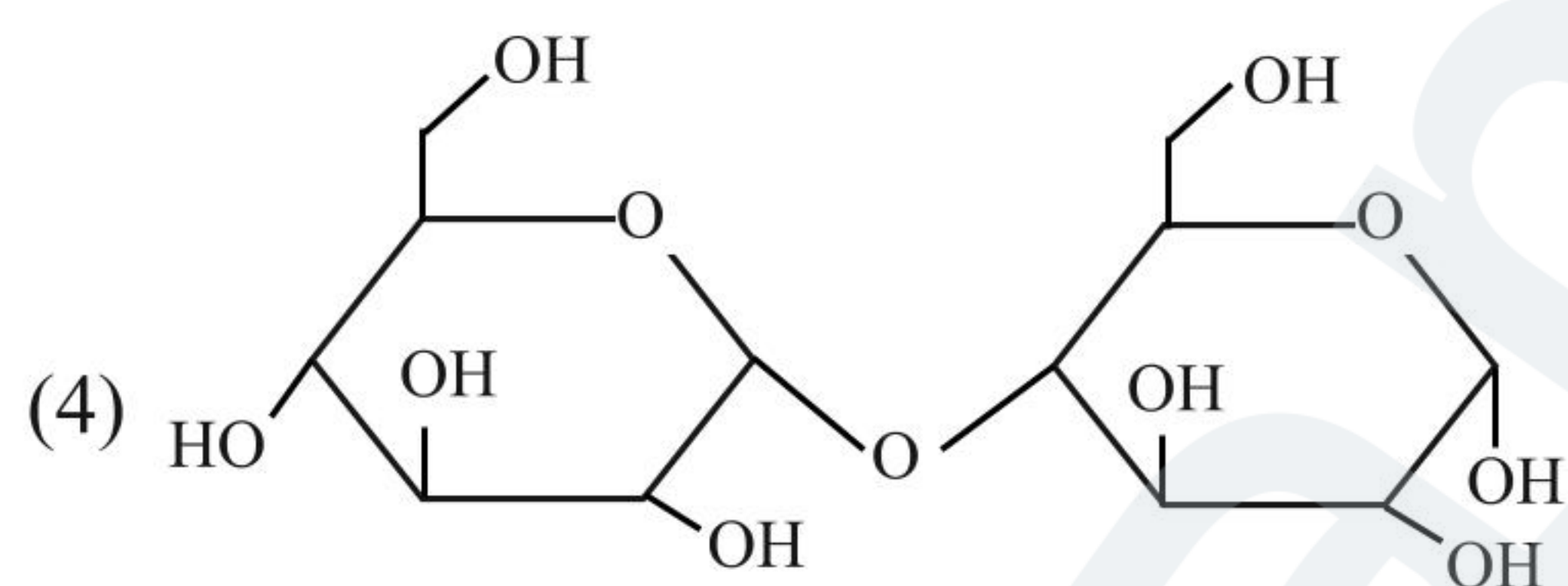
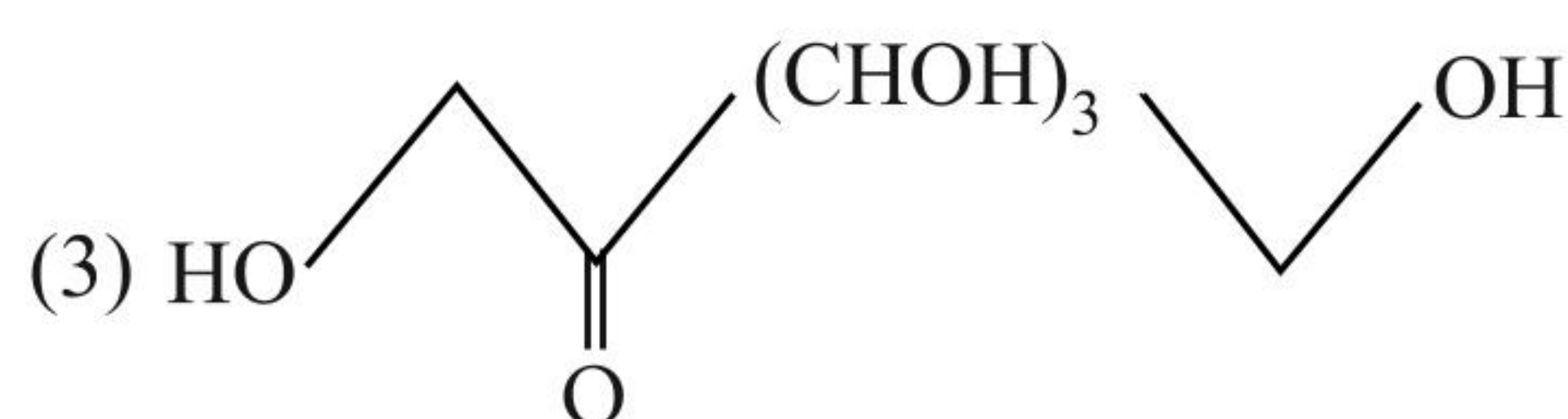
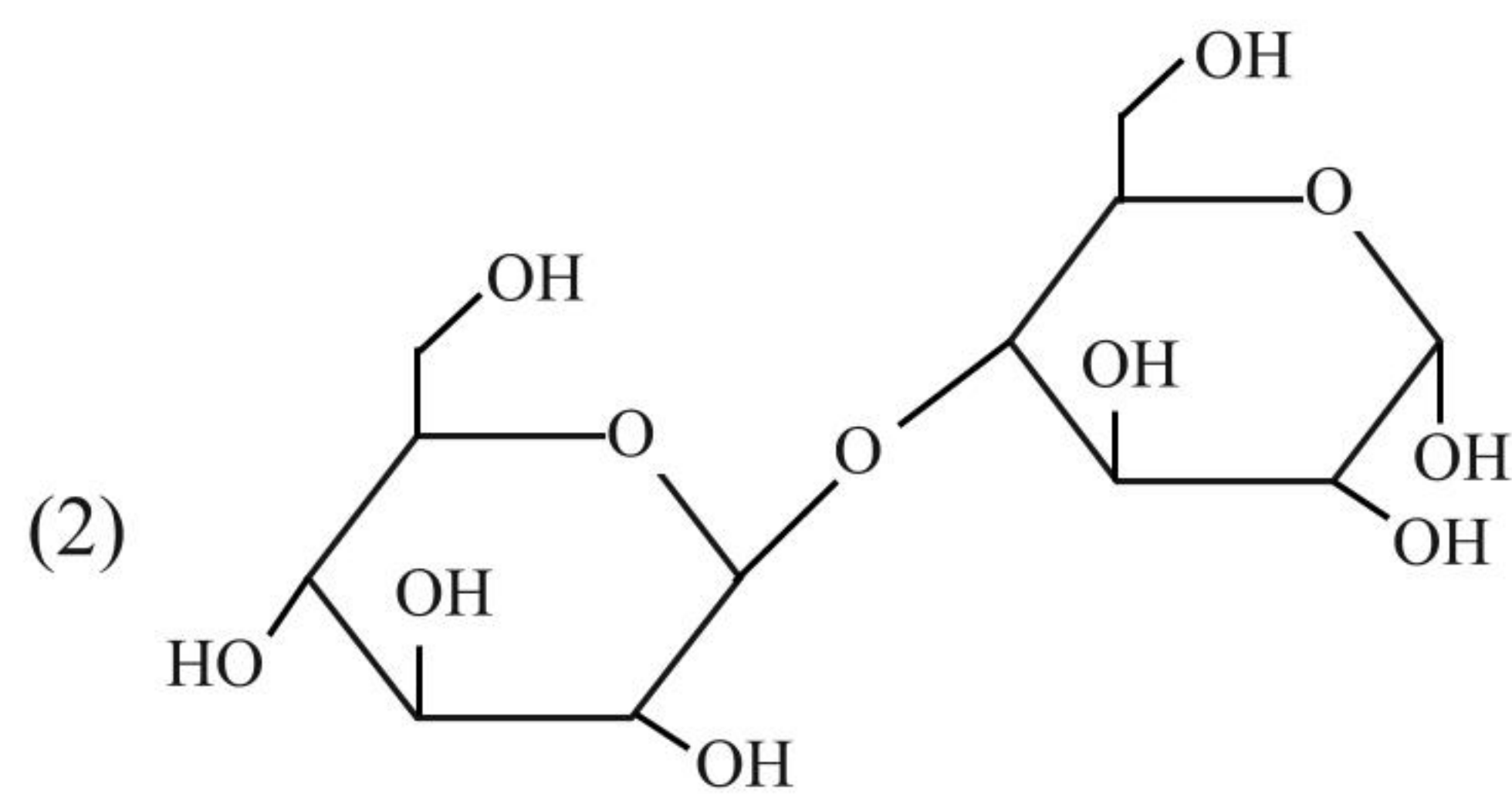
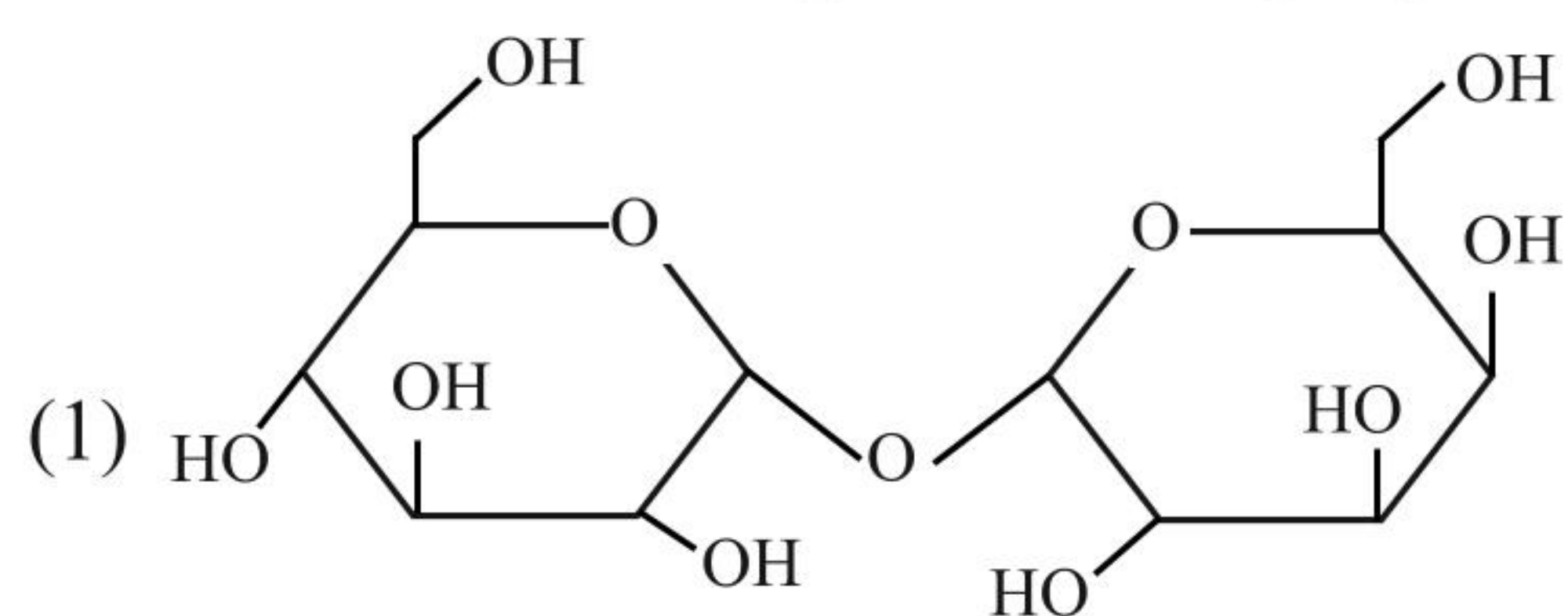
- (4) There is a relationship between the ability of a sugar to mutarotate and to reduce Tollens or Fehling's reagents.

30. D-Glucose and D-fructose both form the same osazone. Which statements are correct about the above reaction?

- (1) Glucose and fructose are epimers.
- (2) Glucose and fructose are anomers.
- (3) The configurations of the OH group at C-3 and C-4 in glucose and fructose are same.
- (4) The configurations of the OH group at C-4 and C-5 in glucose and fructose are same.

Polysaccharides

31. Which of the following are reducing sugar?



32. Which are true?

- (1) Glucose is a disaccharide.
- (2) Starch is a polysaccharide.
- (3) Glucose and fructose are not anomer.
- (4) Invert sugar consist of glucose and fructose.

33. The phenomenon of mutarotation is shown by:

- (1) glucose
- (2) fructose
- (3) cellulose
- (4) starch

34. Which of the following statements are correct ?

- (1) Hydrolysis of sucrose with dilute acid yields an equimolar mixture of D-Glucose and D-Fructose.
- (2) Acidic hydrolysis of sucrose is accompanied by a change in optical reaction.
- (3) In sucrose, the glycosidic linkage is between C—1 glucose and C—2 of fructose.
- (4) Aqueous solution of sucrose exhibits mutarotation.

35. On hydrolysis which of the following carbohydrate give only glucose ?

- (1) Sucrose
- (2) Lactose
- (3) Maltose
- (4) Starch

36. Which of the following do not undergo hydrolysis ?

- (1) Glucose
- (2) Fructose
- (3) Cane sugar
- (4) Maltose

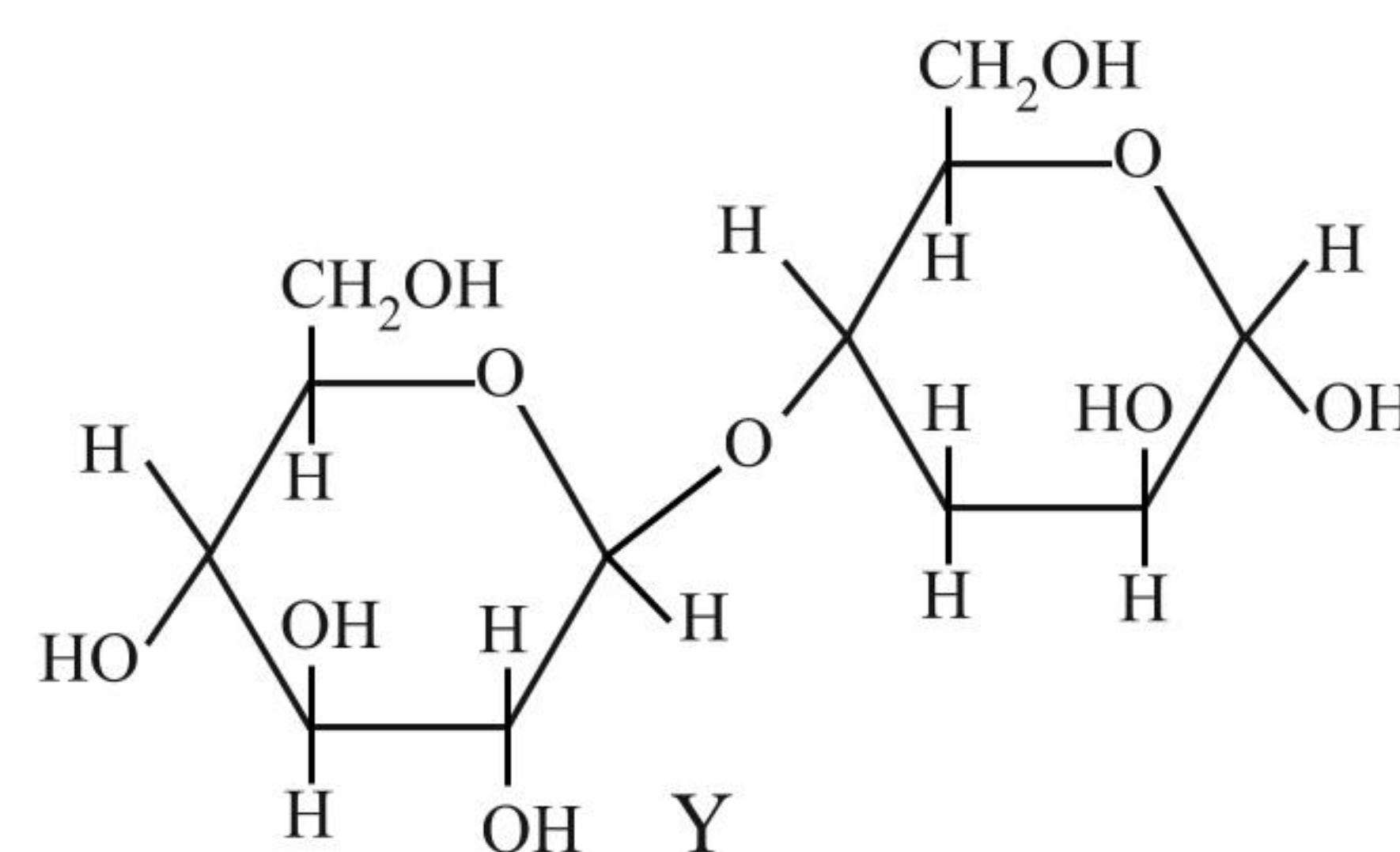
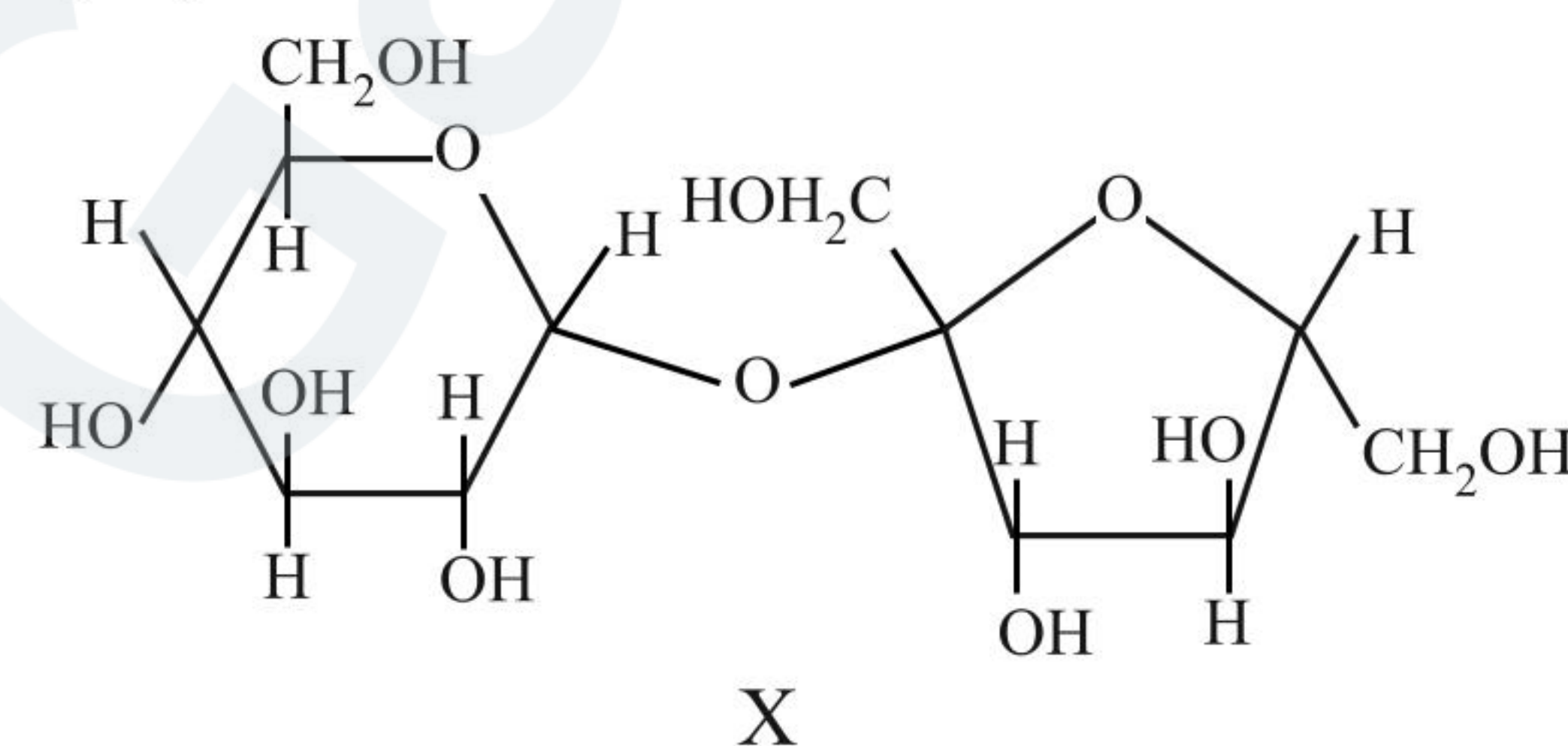
37. Which of the following are disaccharides ?

- (1) Glucose
- (2) Cane sugar
- (3) Maltose
- (4) Starch

38. Which of the following carbohydrate will give the same osazone ?

- (1) Glucose
- (2) Fructose
- (3) Cane sugar
- (4) Lactose

39. The correct statement(s) about the following sugars X and Y is(are):



- (1) X is a reducing sugar and Y is a non-reducing sugar.
- (2) X is a non-reducing sugar and Y is a reducing sugar.
- (3) The glucosidic linkages in X and Y are α and β , respectively.
- (4) The glucosidic linkages in X and Y are β and α , respectively.

40. Which statement(s) is/are correct about sucrose?

- (1) ($C_1-\alpha$) (OH) of glucopyranose is linked with ($C_2-\beta$) (OH) of fructofuranose.
- (2) ($C_1-\alpha$) (OH) of glucopyranose is linked with ($C_2-\beta$) (OH) of fructopyranose.
- (3) It reduces Fehling's solution.
- (4) It exhibits mutarotation.

41. Which statements are correct about sucrose?

- (1) IUPAC name of sucrose is α -D-glucopyranosyl- β -D-fructofuranside.
- (2) IUPAC name of sucrose is β -D-fructofuranosyl- α -D-glucopyranoside.
- (3) It is hydrolysed both by emulsin and amylase.
- (4) On hydrolysis, the solution is laevorotatory.

42. Which statements are correct about sucrose?

- (1) On complete methylation with $\text{Me}_2\text{SO}_4/\text{NaOH}$, it forms an octa-*o*-methyl product.
- (2) On complete acetylation with $\text{Ac}_2\text{O}/\text{NaOAc}$, it forms a hexaacetate product.
- (3) On complete methylation with $\text{Me}_2\text{SO}_4/\text{NaOH}$, it forms hexa-*o*-methyl product.
- (4) On complete acetylation with $\text{Ac}_2\text{O}/\text{NaOAc}$, it forms octa-acetate product.

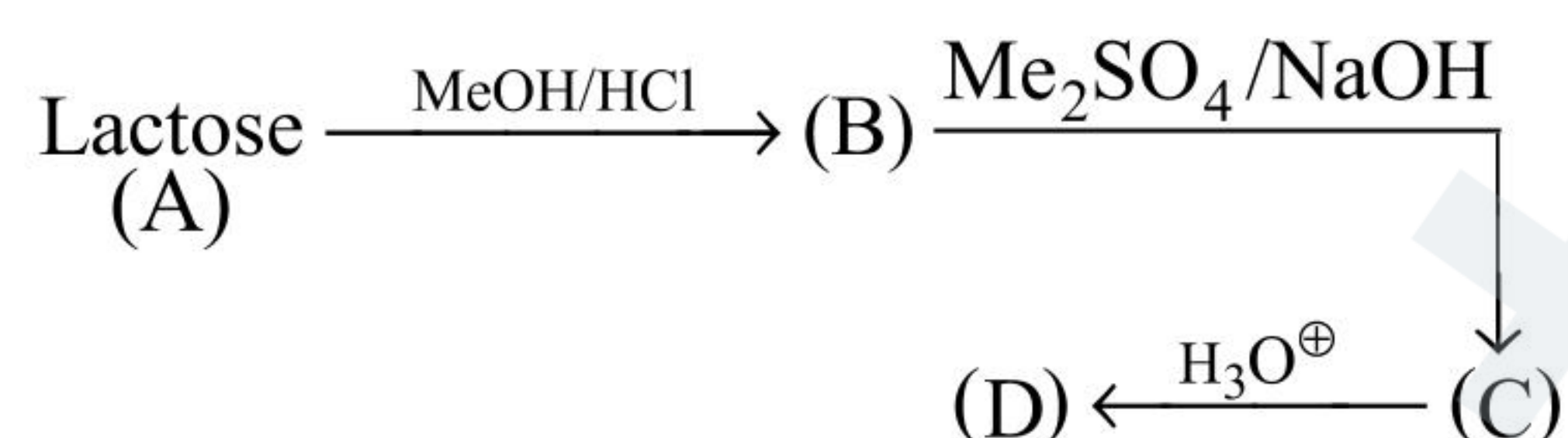
43. Which statements are correct about lactose?

- (1) $(\text{C}_1-\beta)$ (OH) of glucose is linked with (C_4-OH) of galactose.
- (2) $(\text{C}_1-\beta)$ (OH) of galactose is linked with (C_4-OH) of β -glucose.
- (3) It is hydrolysed both by amylase and lactase.
- (4) It exhibits mutarotation.

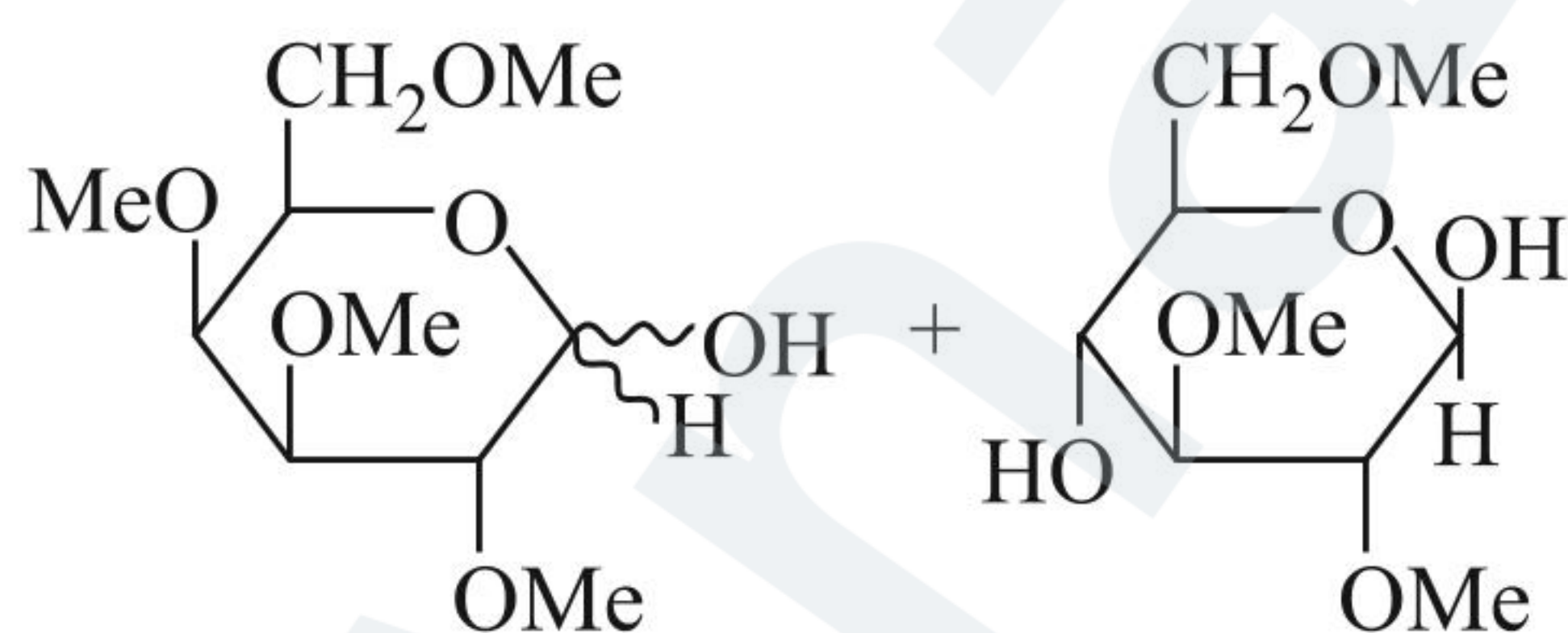
44. Which statements are correct about lactose?

- (1) IUPAC name of lactose is β -D-galactopyranosyl- β -D-glucopyranoside.
- (2) IUPAC name of lactose is β -D-glucopyranosyl β -D-galactopyranoside
- (3) On methylation with MeOH/HCl , it gives methyl- β -D-galactopyranosyl- β -D-glucopyranoside.
- (4) On methylation with MeOH/HCl , it gives methyl- β -D-glucopyranosyl- β -D-galactopyranoside.

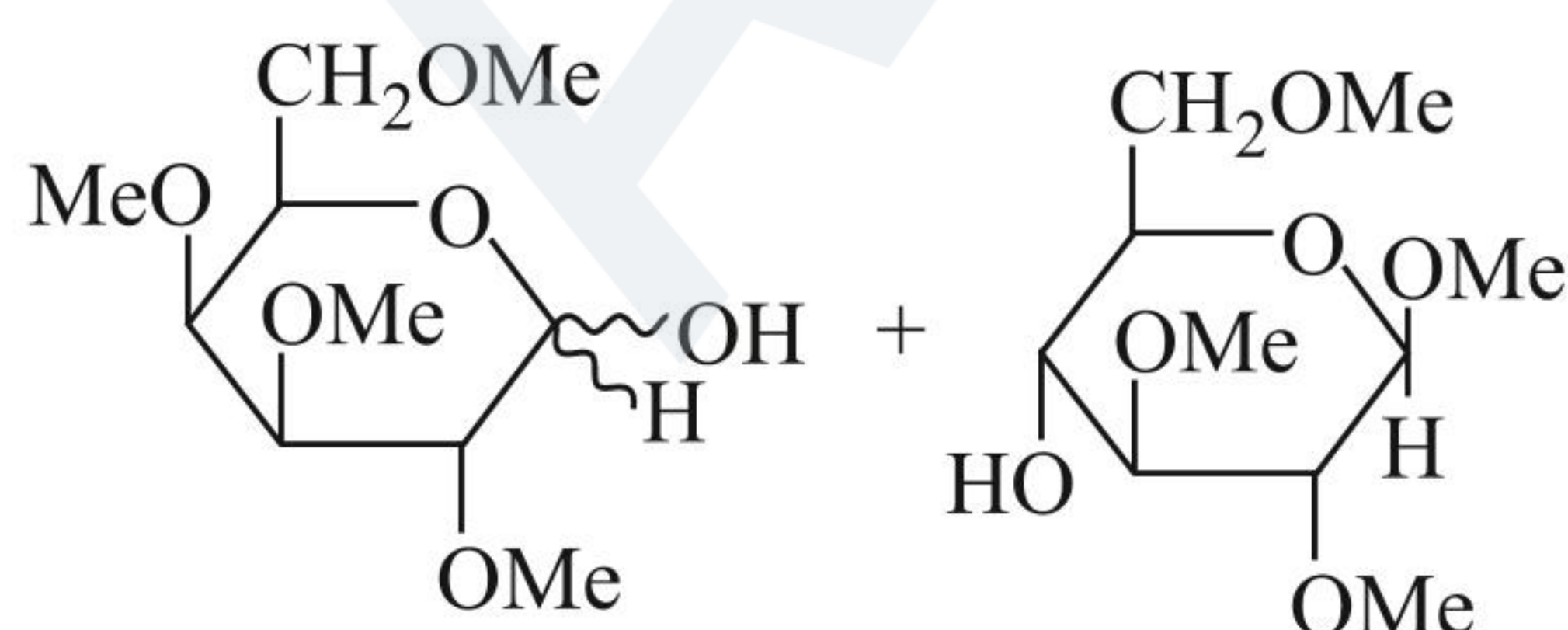
45. Which statements are correct about the reaction of lactose?



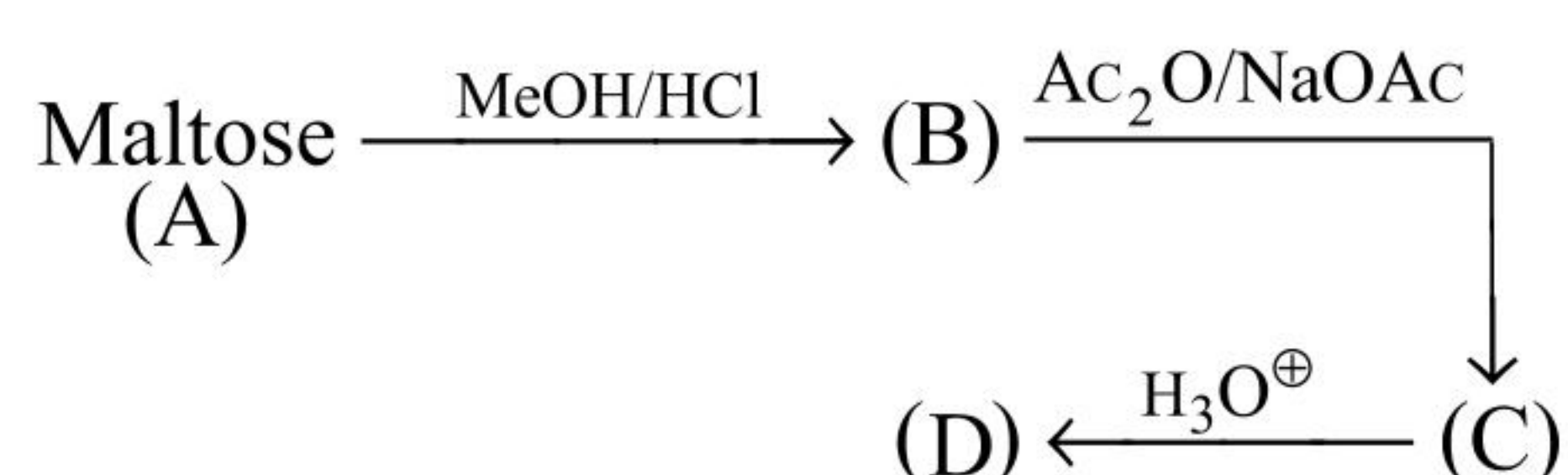
- (1) The product (C) is methyl-hepta-*o*-methyl- β -D-galactopyranosyl- β -D-glucopyranoside.
- (2) The product (C) is methyl-octa-*o*-methyl- β -D-galactopyranosyl- β -D-glucopyranoside.
- (3) Products (D) are:



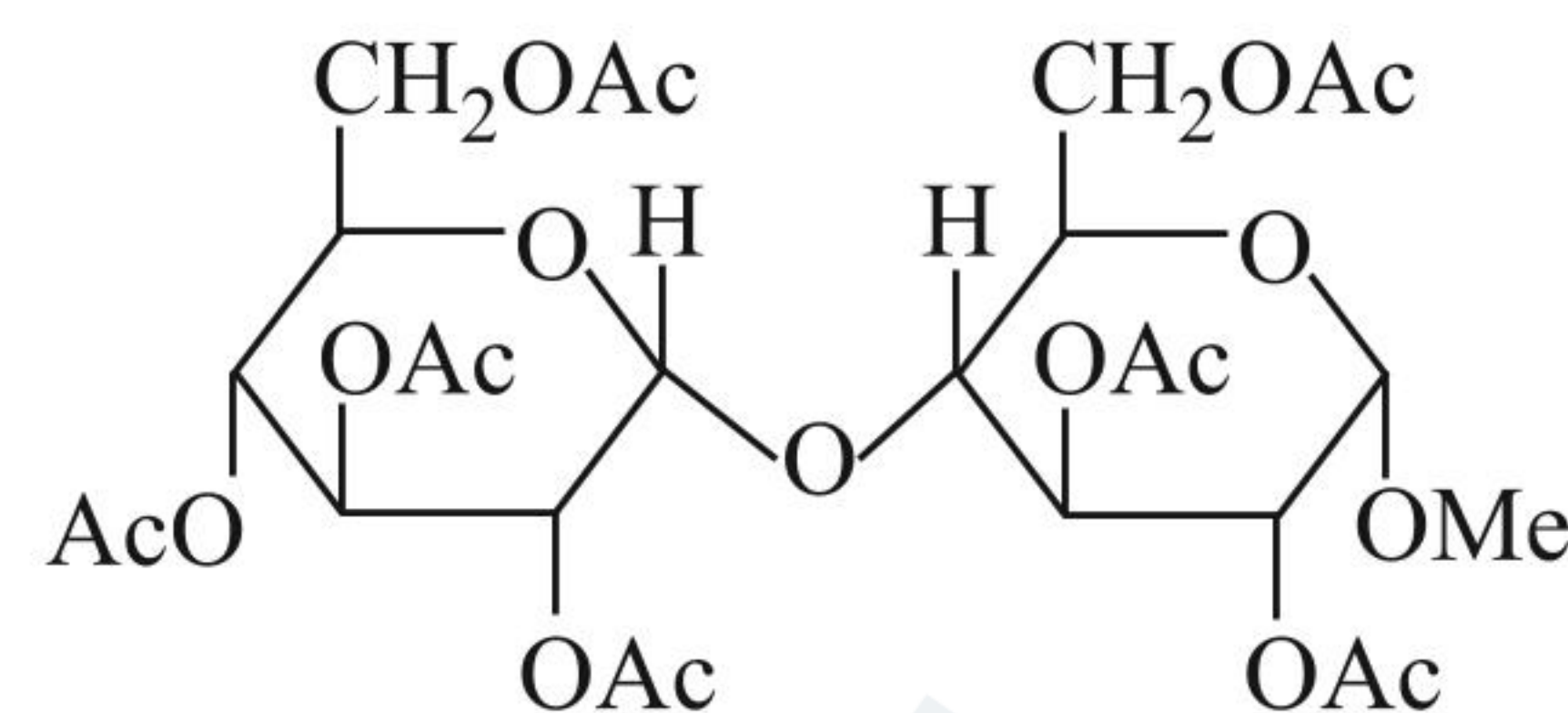
- (4) Products (D) are:



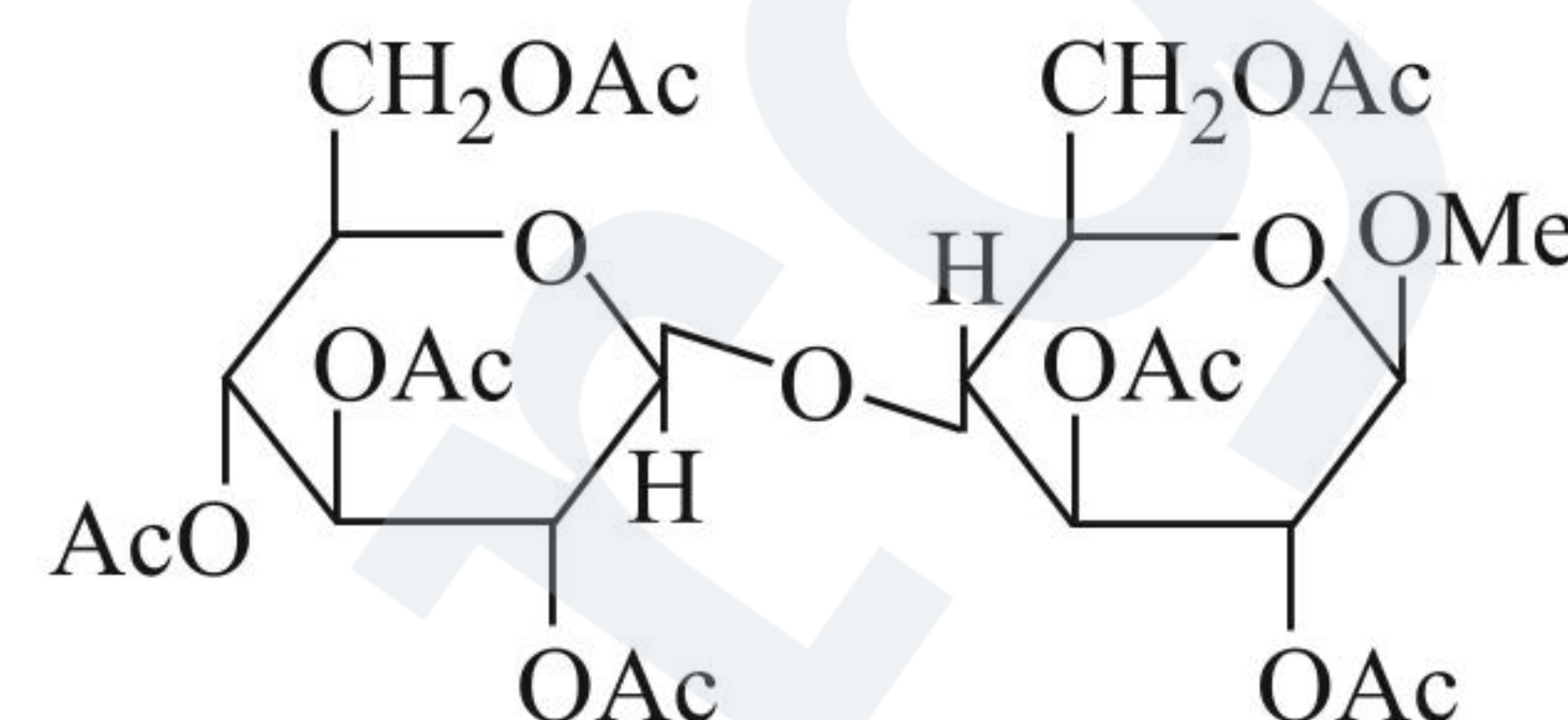
46. Which statements are correct about the reaction of maltose?



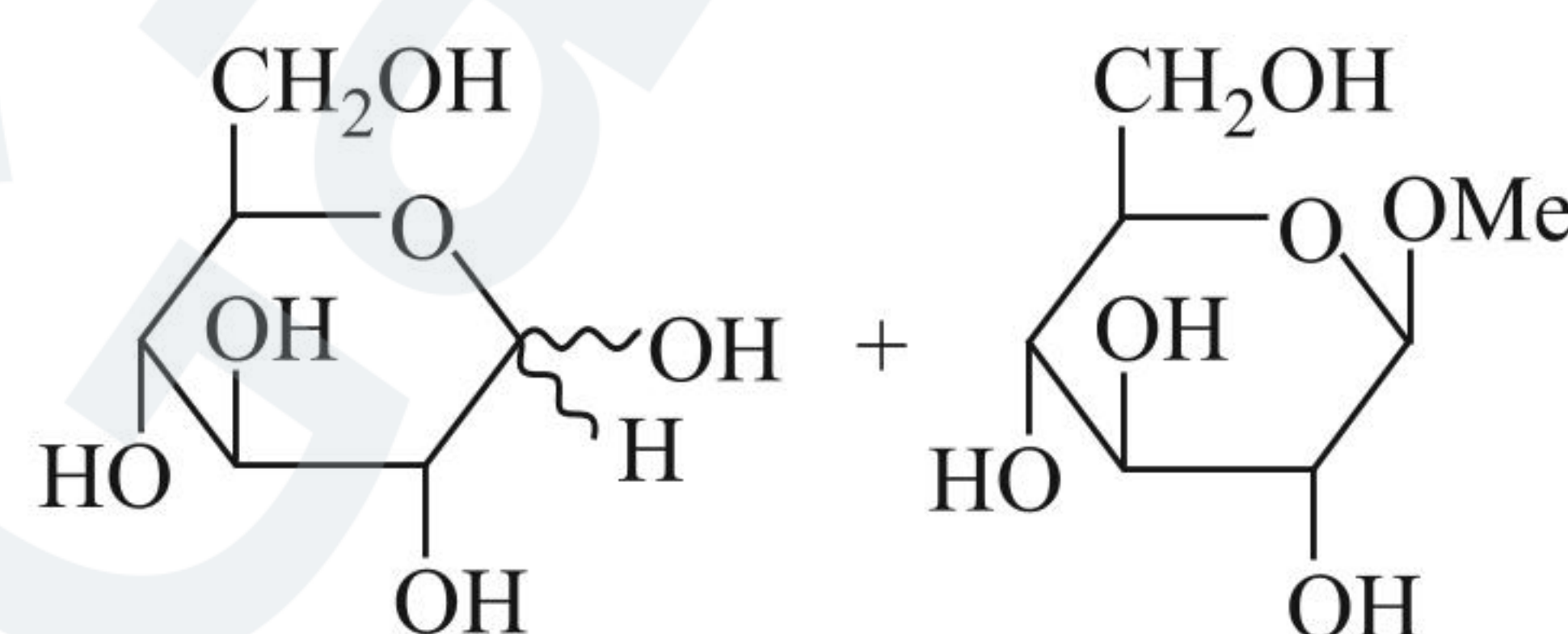
(1) Product (C) is:



(2) Product (C) is:



(3) Products (D) are:



(4) Products (D) are 2 mol α - and β -D-glucose.

47. Which statements are correct?

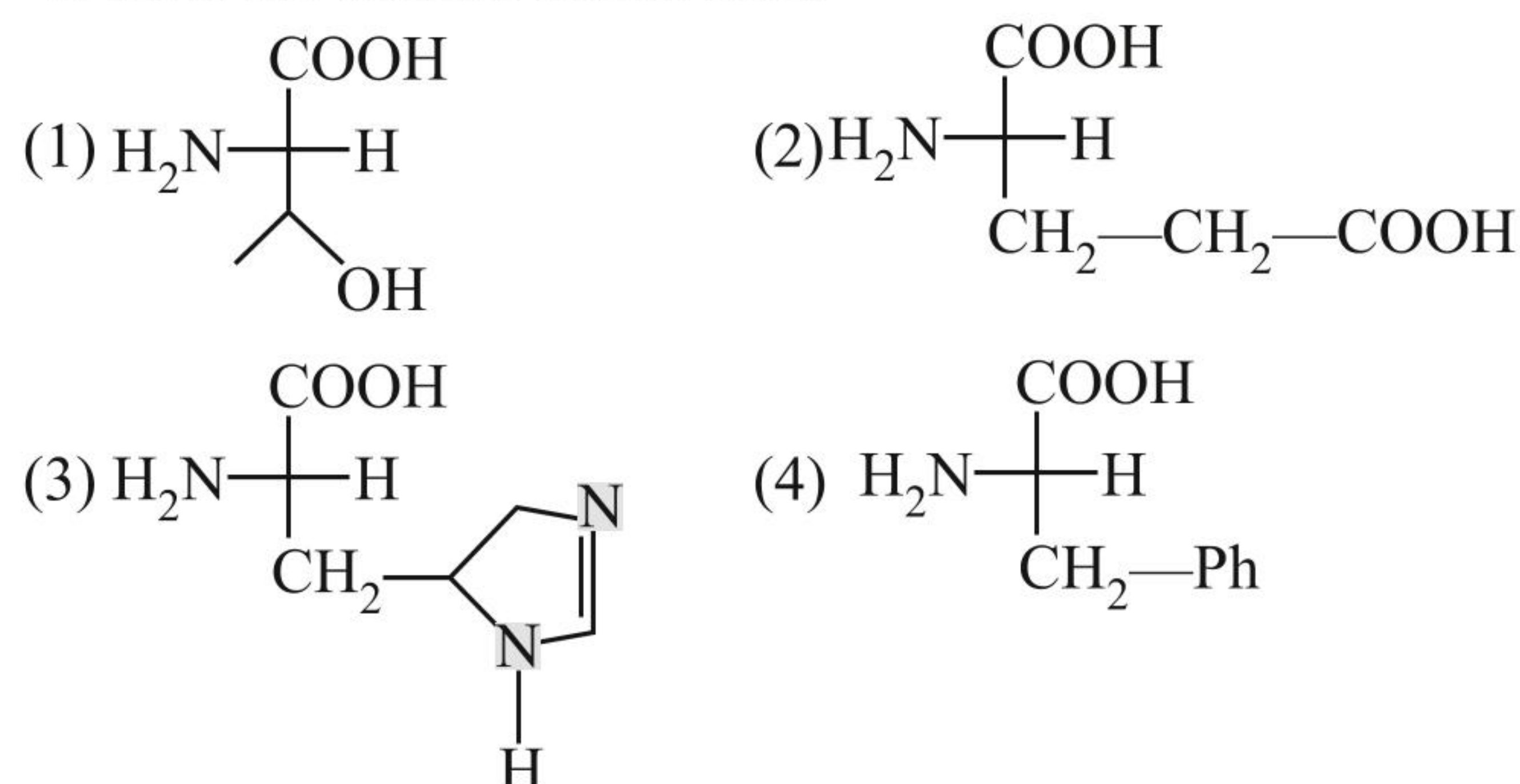
- (1) Lactose is a disaccharide and is a reducing sugar.
- (2) α -D-glucopyranose and β -D-glucopyranose are anomers.
- (3) Methyl- α -D-glucopyranoside has an acetal structure and is a non-reducing sugar.
- (4) α -D-Glucopyranose has a hemiacetal structure and is a reducing sugar.

Amino acids, Proteins, Nucleic acid and Vitamins

48. Globular protein is present in:

- (1) Blood
- (2) Milk
- (3) Eggs
- (4) Cellulose

49. Choose the neutral amino acid:



50. Consider the following statements about amino acids:

- (1) the amino acids that constitute proteins are all *L*-amino acids.
- (2) among the 20 amino acids that constitute proteins, glycine is the only one that does not possess chiral center.
- (3) an important and sensitive test for the detection of *L*-amino acid is the ninhydrin colour test.
- (4) HNO_2 liberates nitrous oxide from amino acid.

51. Which of the following statements are correct with reference to isoelectric point ?

- (1) It is the point at which amino acids bear no net charge.
- (2) It corresponds to the pH at which concentration of zwitter ion is maximum.
- (3) At isoelectric point amino acid exists as a base.
- (4) None of the above.

52. Which of the following statements are correct with reference to amino acid ?

- (1) A carboxylic acid that contains an amino group.
- (2) Amino acids are the building blocks of peptides and proteins.
- (3) An amino acid may exist as a zwitter ion under suitable conditions.
- (4) Amino acids are negatively charged in basic medium.

53. The **correct** structure of glycine at given pH are:

- (1) $\text{H}_3\text{N}^+\text{CH}_2-\text{C}(=\text{O})\text{OH}$ at pH = 2.0
- (2) $\text{H}_3\text{NCH}_2-\text{C}(=\text{O})\text{O}^-$ at pH = 6.0
- (3) $\text{H}_2\text{NCH}_2-\text{C}(=\text{O})\text{O}^-$ at pH = 9
- (4) $\text{H}_2\text{NCH}_2-\text{C}(=\text{O})\text{OH}$ at pH = 12

54. Which forms Zwitter ion?

- (1) Glycine
- (2) Sulphanilic acid
- (3) Anthranilic acid
- (4) Salicylic acid

55. Alanine forms Zwitter ion which exists as:

- (1) $\text{CH}_3-\text{CH}(\text{NH}_3^+)\text{COO}^-$ in acidic medium
- (2) $\text{CH}_3-\text{CH}(\text{NH}_3^+)\text{COOH}$ in medium of pH = 4
- (3) $\text{CH}_3-\text{CH}(\text{NH}_3^+)\text{COOH}^-$ in a medium of pH = 13
- (4) $\text{CH}_3-\text{CH}(\text{NH}_3^+)\text{COO}^-$ in a medium of pH = 2

56. Which of the following statements are correct about α -amino acids.

- (1) All the amino acids which constitute proteins have D-configuration.
- (2) Isoelectric point of glycine is 6.1.
- (3) Valine is an essential amino acid.
- (4) In α -amino acids, the basic group is $(-\text{COO}^-)$ and acidic group is $(-\text{NH}_3^+)$.

57. How many base pairs in the gene are needed to code for the enzyme lysozyme, containing 129 amino acids, found in egg white?

- (1) 3×129
- (2) $(3 \times 129) + (3 \times 2) = 393$ base pairs
- (3) $(3 \times 129) + (3 \times 3) = 396$ base pairs
- (4) 4×129

58. Which of the following contain disulphide linkages?

- (1) Oxytocin
- (2) Vasopressin
- (3) Insulin
- (4) Haemoglobin

59. Globular proteins are present in:

- (1) Eggs
- (2) Muscles
- (3) Keratin
- (4) Blood

60. Which of the statements are correct about D, L of sugars and amino acids.

- (1) In sugars, symbols D and L refer to the relative configuration of the OH groups at the penultimate C atom w. r.t. to glyceraldehyde taken as standard. D refers to $(-\text{OH})$ group on R.H.S. and L refers to OH group on L.H.S.

- (2) In amino acids, symbols D and L refer to the relative configuration of the (NH_2) group w.r.t. D (+) serine

taken as standard $\left(\begin{array}{c} \text{COOH} \\ | \\ \text{H}-\text{C}-\text{NH}_2 \\ | \\ \text{CH}_2\text{OH} \end{array} \right)$ [D (+) Serine].

D refers to NH_2 group on R.H.S. and L refers to $(-\text{NH}_2)$ group on L.H.S.

- (3) In sugars, D refers to dextrorotatory and L refers to laevorotatory.
- (4) In amino acids, D refers to positive and L refers to negative optical rotation.

61. A mixture of three proteins, (A) (pepsin), (B) (haemoglobin), and (C) (lysozyme) was separated by electrophoresis method at pH = 7. The pH at isoelectric point (pI) of the proteins are pI of (A), (B), and (C) which are 1.1, 6.7, and 11.0, respectively. Which of the statement are correct?

- (1) Pepsin (A) will migrate to the cathode.
- (2) Lysozyme (C) will migrate to the anode.
- (3) Haemoglobin will not migrate.
- (4) At pH = 7, (A) and (C) would precipitate out while (B) would remain in the solution.

62. Which statements are correct about the mixture of lysine (pI = 9.6) and glycine (pI = 5.97), separated by electrophoresis method or by solubility method?

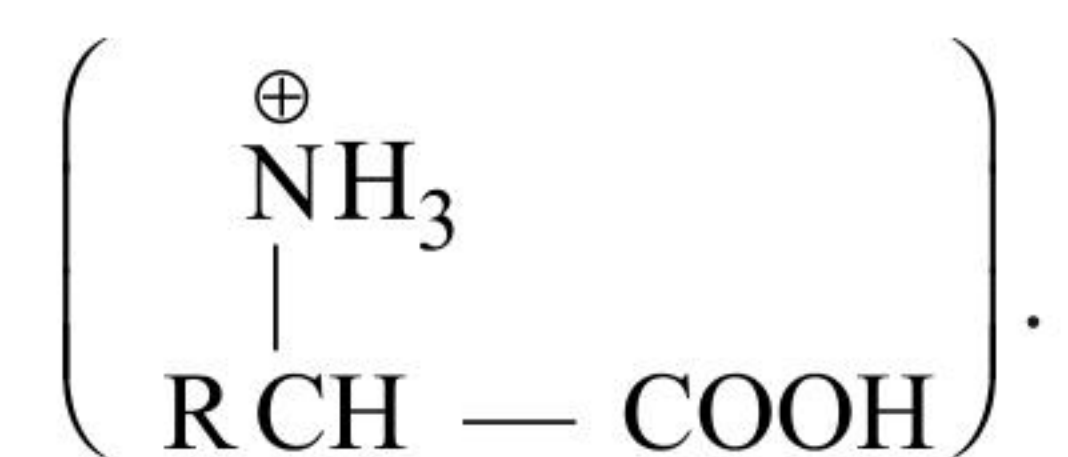
- (1) At pH = 5.97, glycine does not migrate while lysine moves to the cathode.
- (2) At pH = 5.97, glycine does not migrate while lysine moves to the anode.
- (3) At pH = 9.6, lysine does not migrate while glycine moves to the anode.
- (4) At pH = 5.97 of the mixture of the solution, glycine precipitates out while lysine remains in the solution

63. The structure of aspartic acid is given below.



and pK_{a3} of (A), respectively, are: 1.88, 3.65, and 9.60.

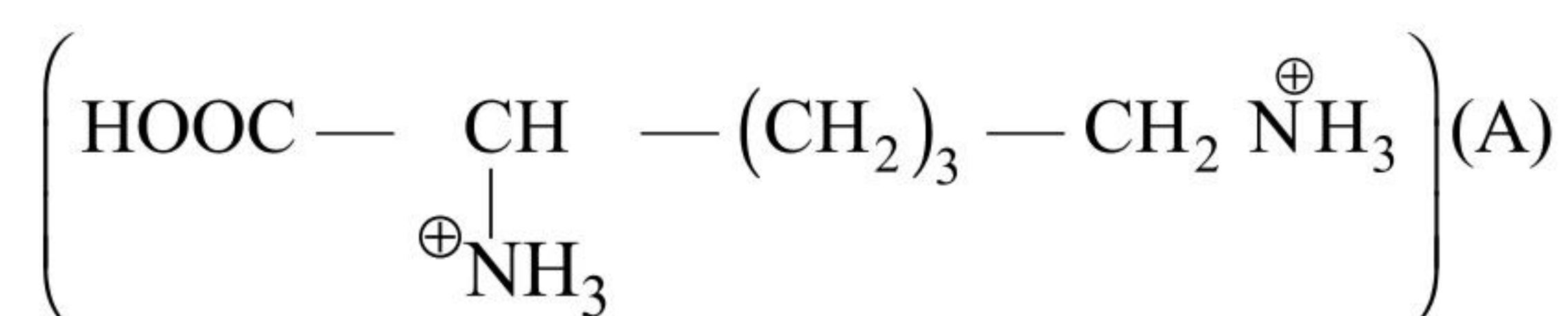
pK_{a1} corresponds to the ionisation of the COOH group, of



pK_{a2} corresponds to the ionisation of $\left(\text{NH}_3^+ \right)$ (ammonium ion). What is the pH at isoelectric points (pI)?

- (1) $\frac{pK_{a1} + pK_{a2}}{2}$ (2) $\frac{pK_{a1} + pK_{a3}}{2}$
 (3) $\frac{pK_{a2} + pK_{a3}}{2}$ (4) $\frac{pK_{a1} + pK_{a2} + pK_{a3}}{3}$

64. The structure of a basic amino acid, lysine, is given below:



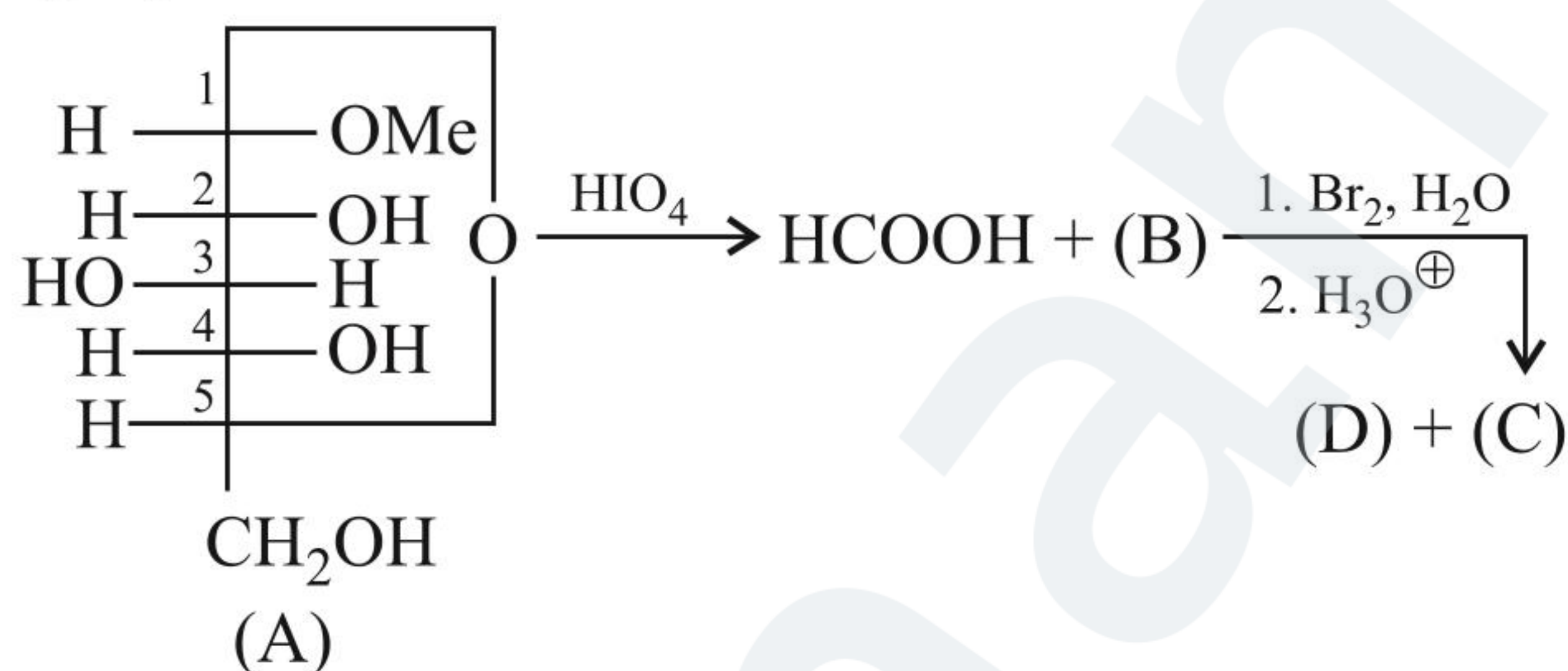
The pK_{a1} , pK_{a2} , and pK_{a3} of (A), respectively, are:
 2.18, 8.95, and 10.53.

What is the pH at isoelectric points (pI)?

- (1) $\frac{pK_{a1} + pK_{a2}}{2}$ (2) $\frac{pK_{a1} + pK_{a3}}{2}$
 (3) $\frac{pK_{a2} + pK_{a3}}{2}$ (4) $\frac{pK_{a1} + pK_{a2} + pK_{a3}}{3}$

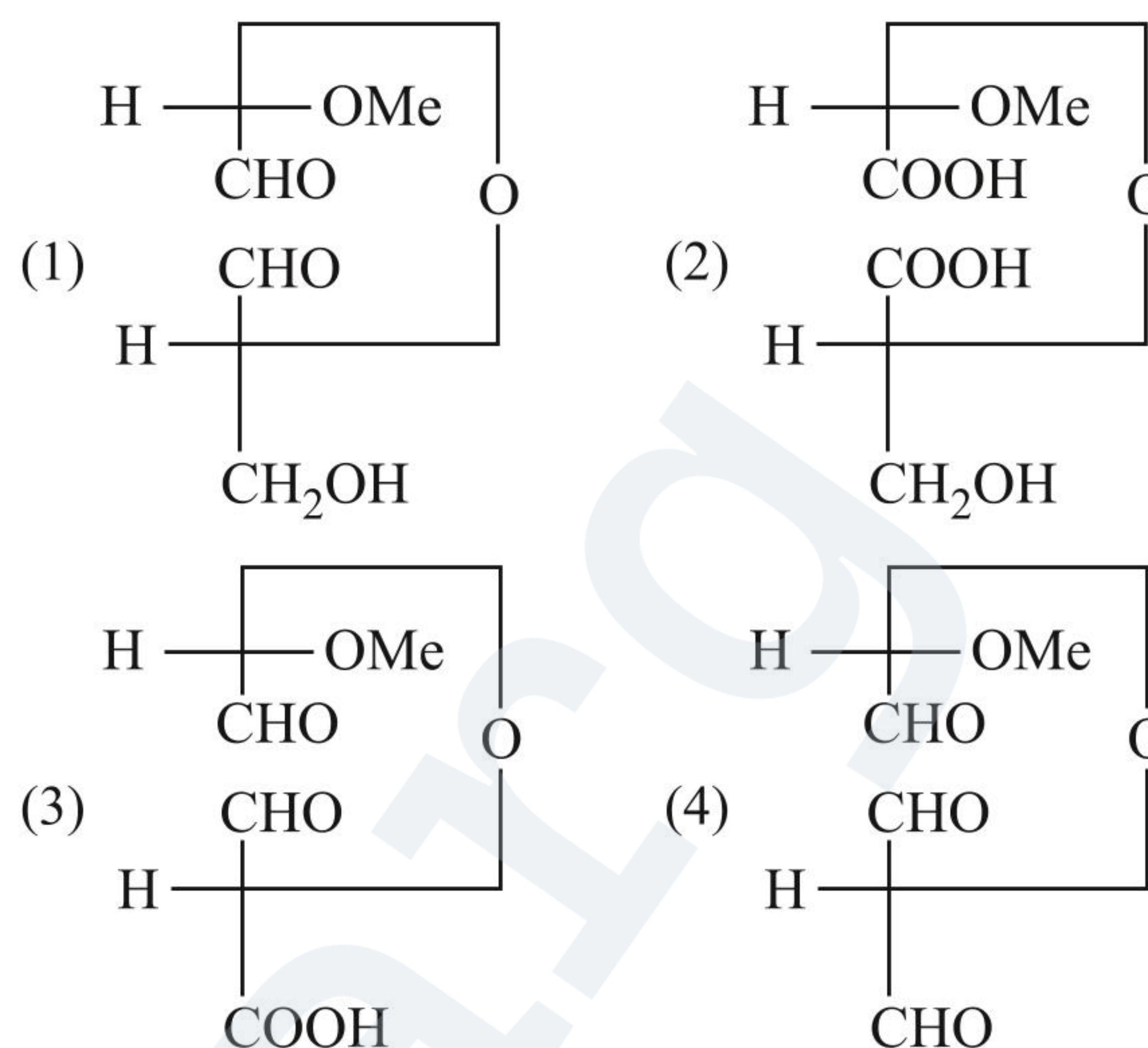
Linked Comprehension Type

Paragraph 1

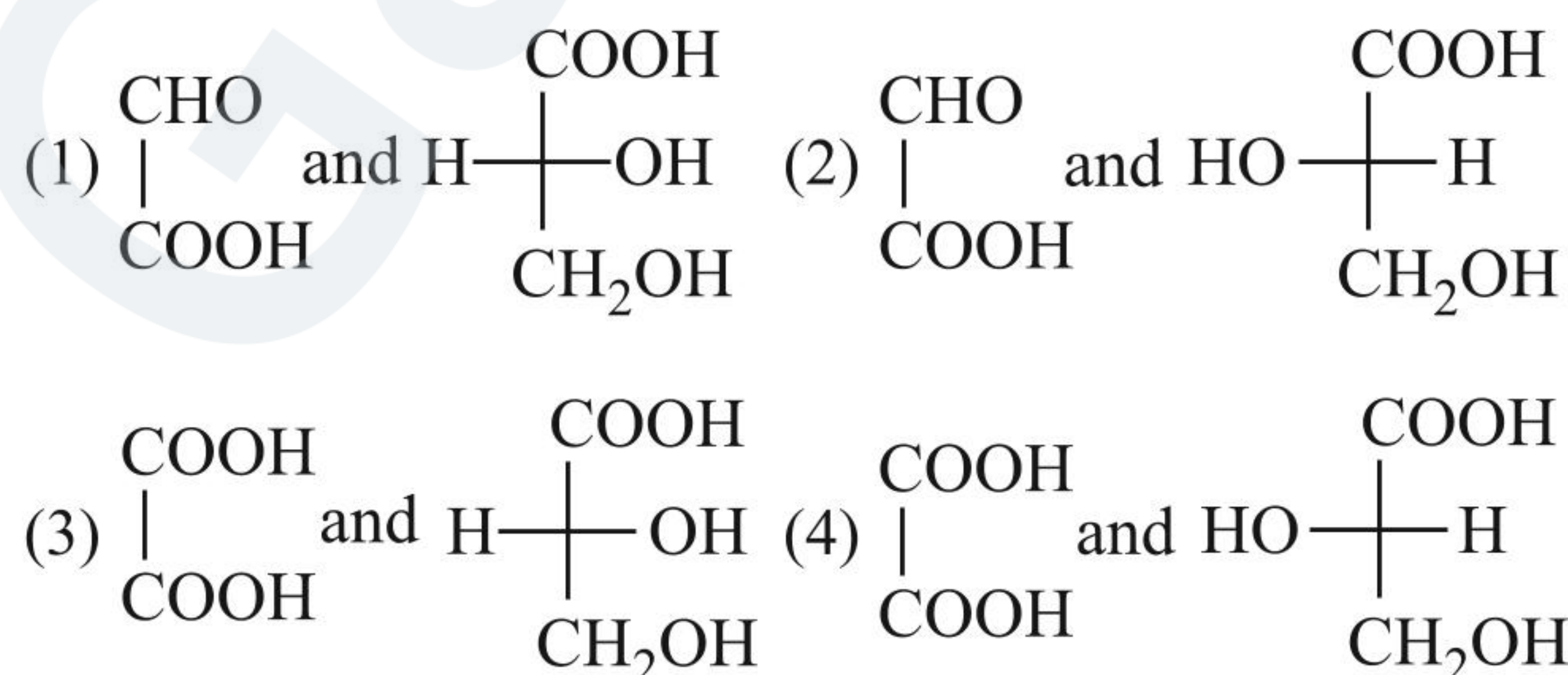


- The name of compound (A) is:
 (1) Methyl- α -D-glucofuranoside
 (2) Methyl- β -D-glucofuranoside
 (3) Methyl- α -D-glucopyranoside
 (4) Methyl- β -D-glucopyranoside
- The number of moles of HIO_4 required in the above reaction is:
 (1) One (2) Two
 (3) Three (4) Four

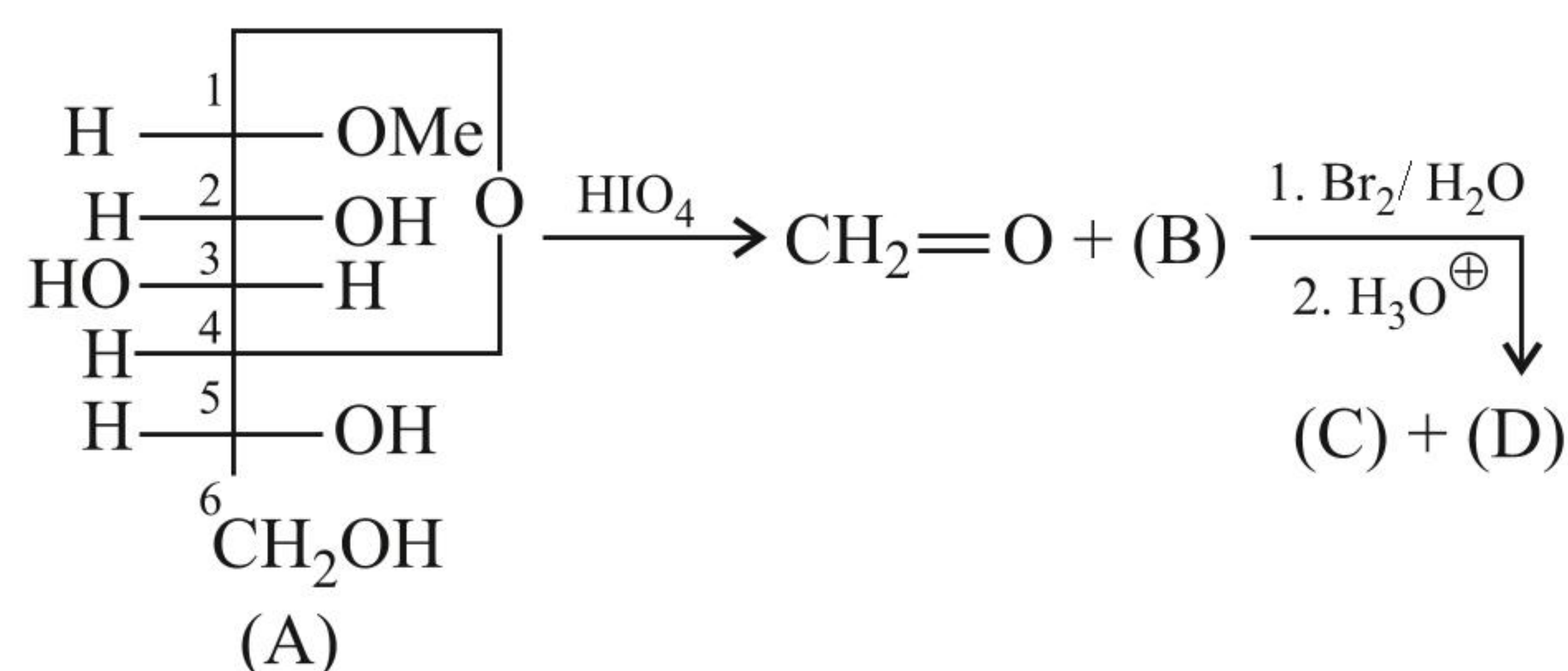
3. The structure of (B) is:



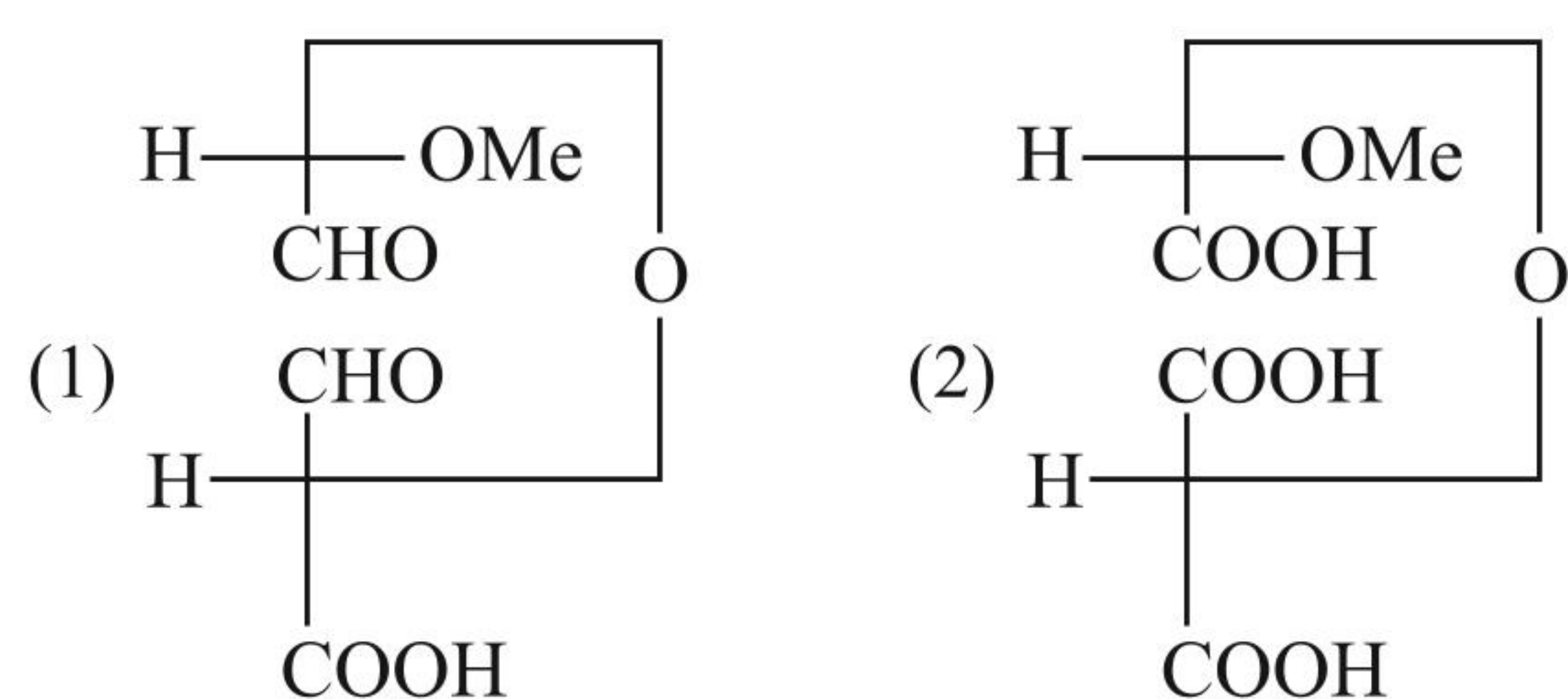
4. Compounds (C) and (D) are:

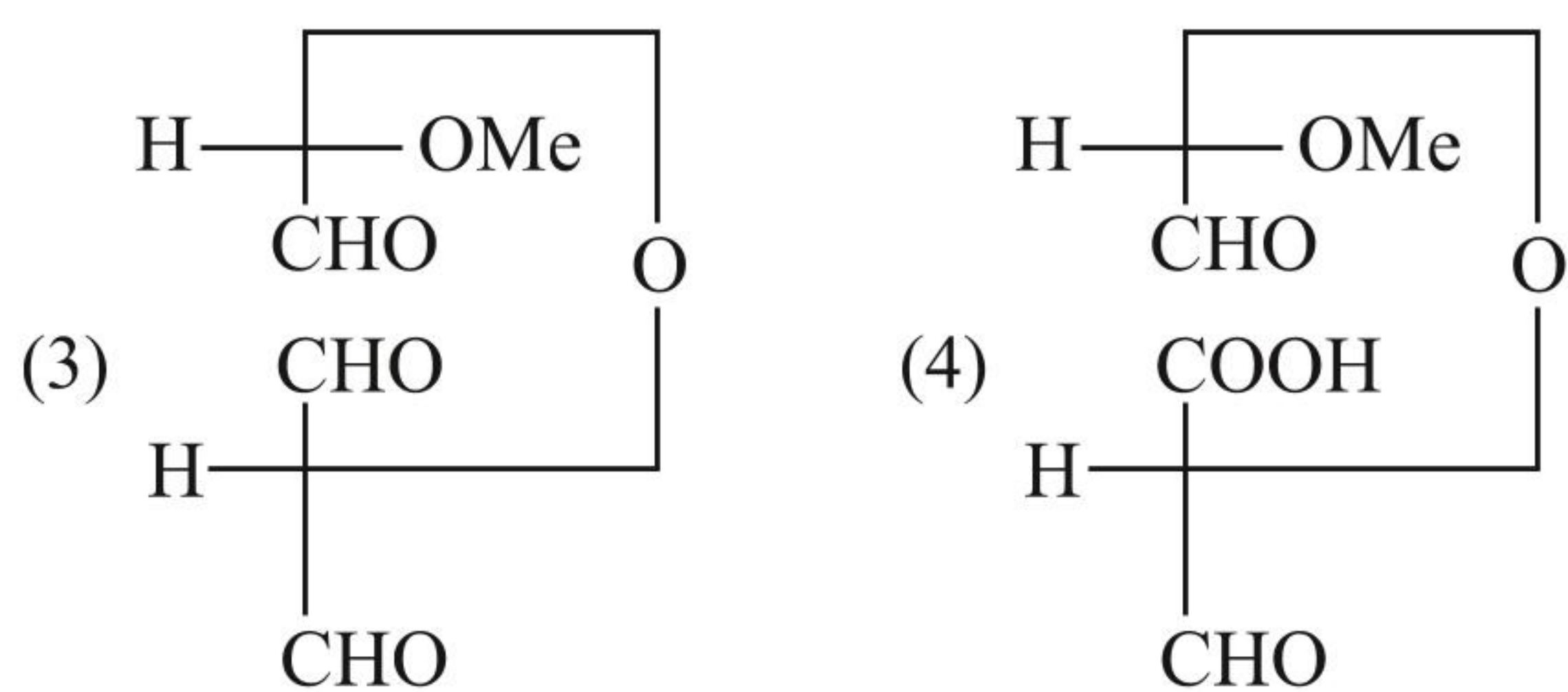


Paragraph 2

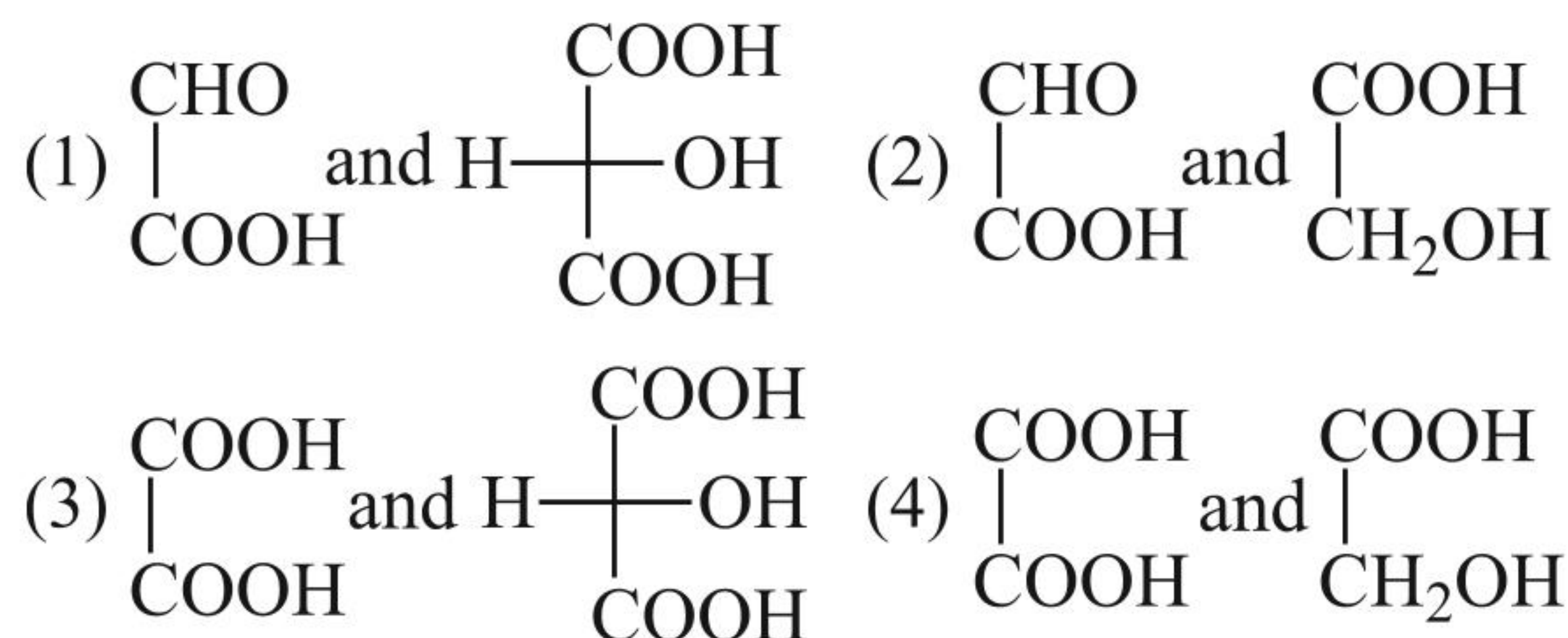


- The name of compound (A) is:
 (1) Methyl- α -D-glucofuranoside
 (2) Methyl- β -D-glucofuranoside
 (3) Methyl- α -D-glucopyranoside
 (4) Methyl- β -D-glucopyranoside
- The number of moles of HIO_4 required in the above reaction is:
 (1) One (2) Two
 (3) Three (4) Four
- The structure of (B) is:

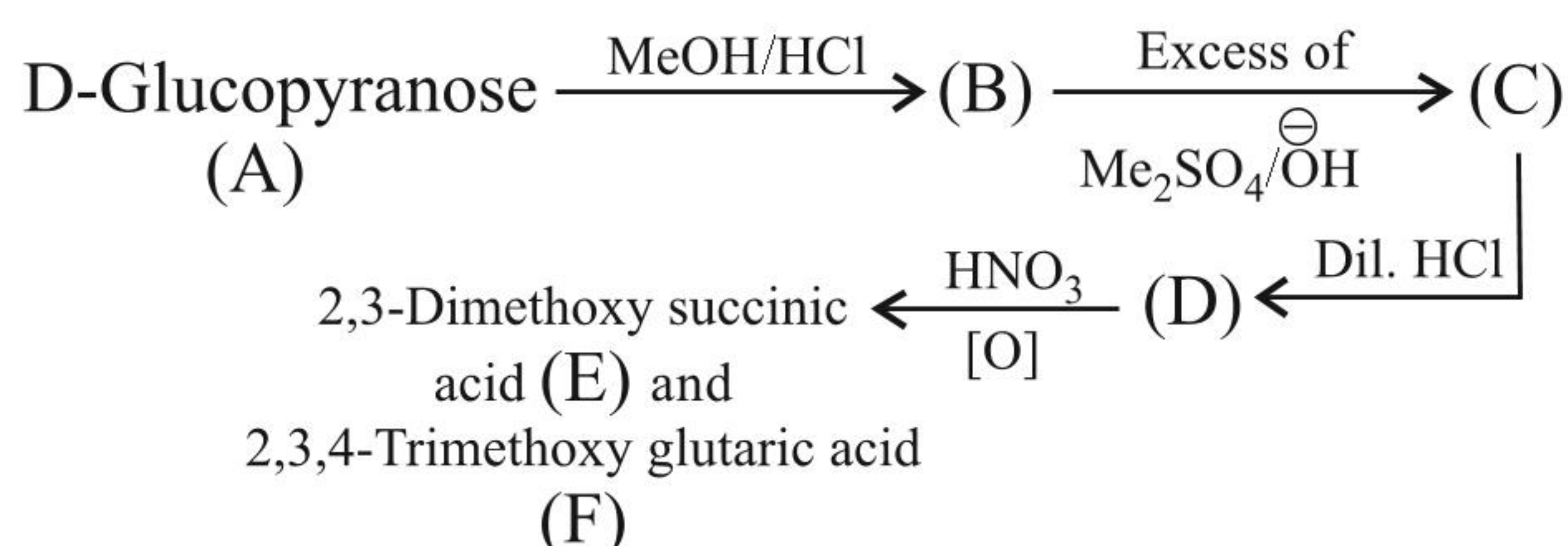




8. Compounds (C) and (D) are:



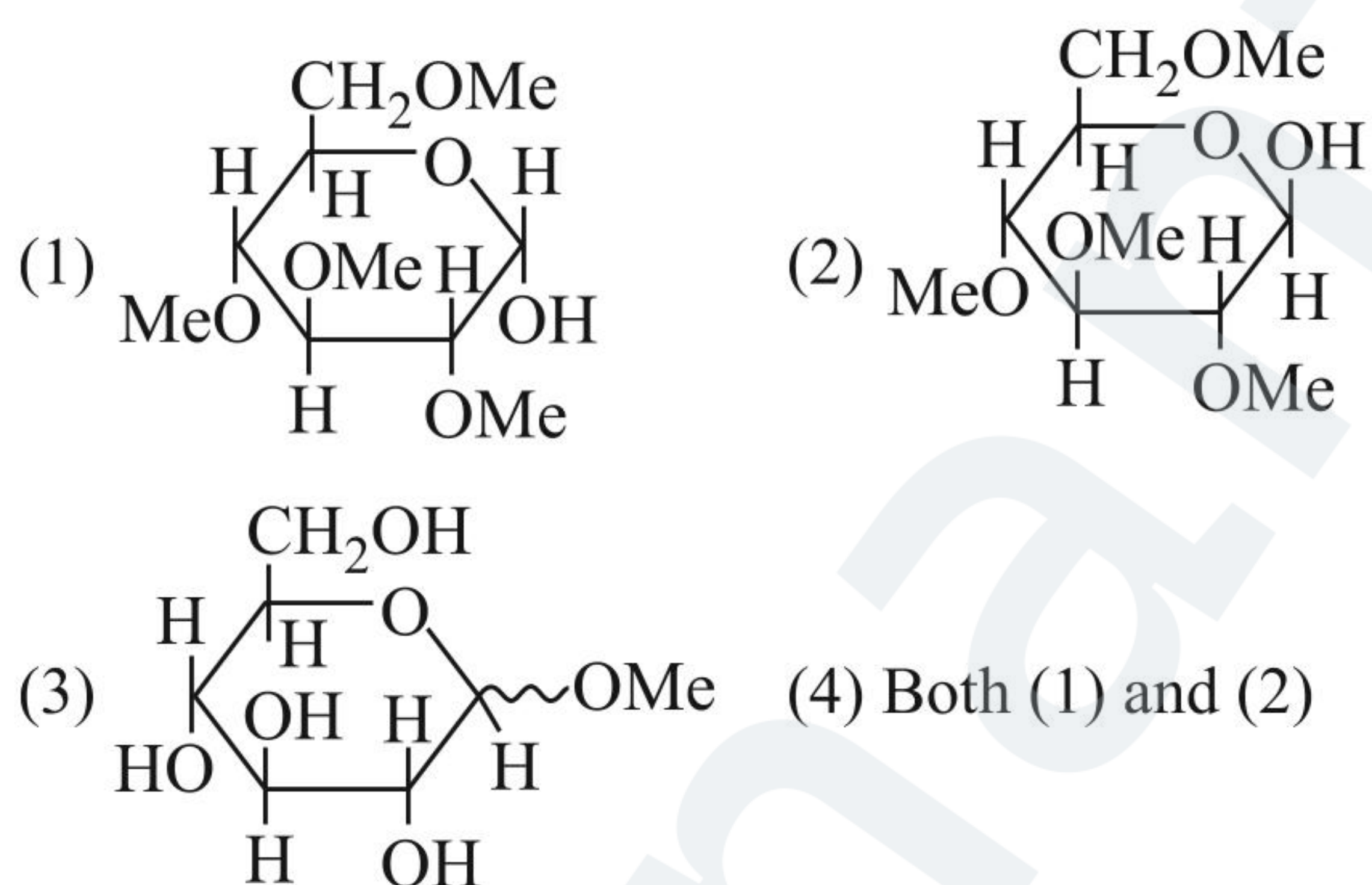
Paragraph 3



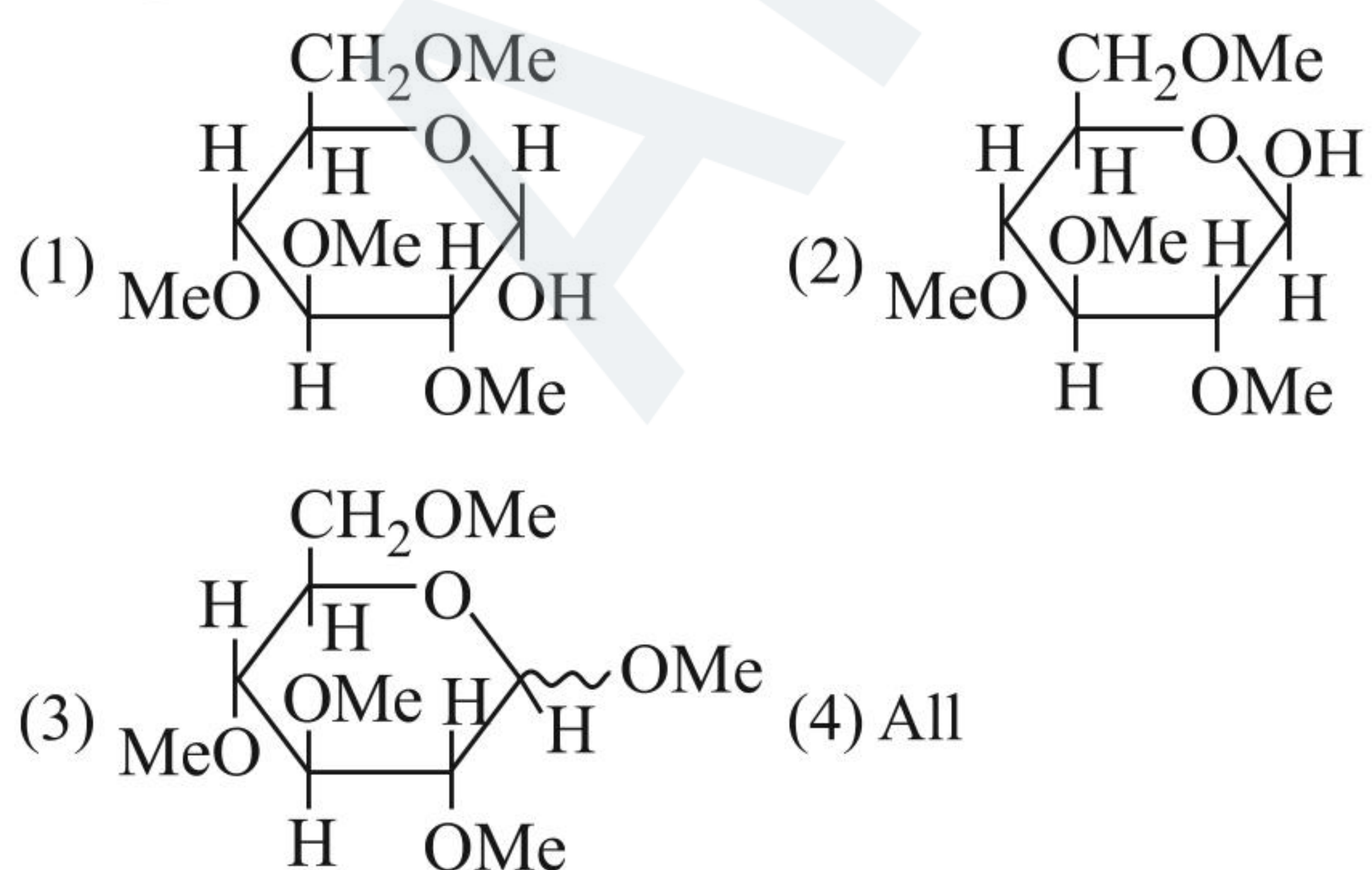
9. Which statement(s) is/are correct about (A)?

- (1) It contains an acetalic linkage.
- (2) It contains a hemiacetalic linkage.
- (3) It has a six-membered cyclic ring.
- (4) It has a δ -hemiacetalic linkage.

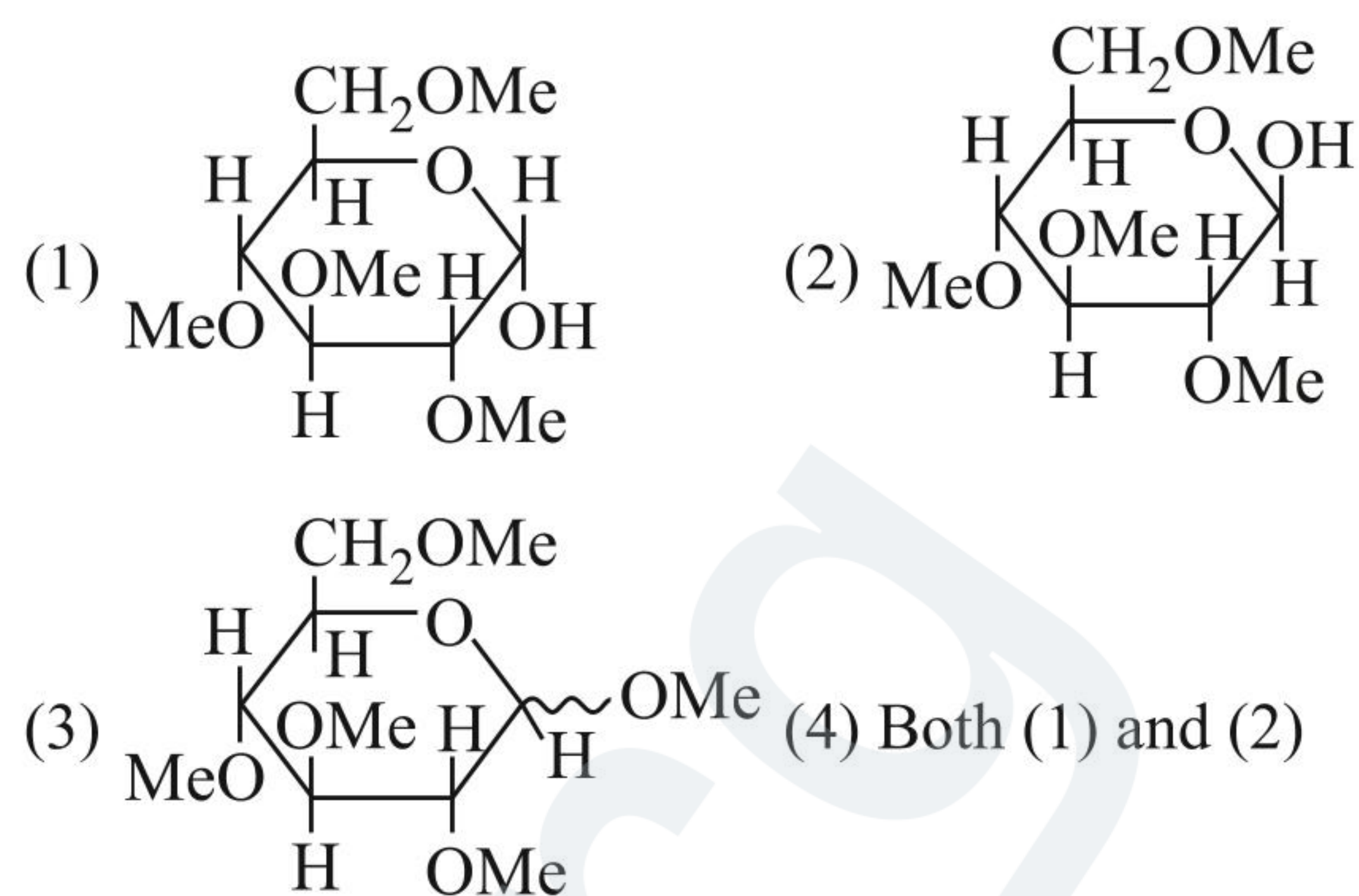
10. Compound (B) is:



11. Compound (C) is:



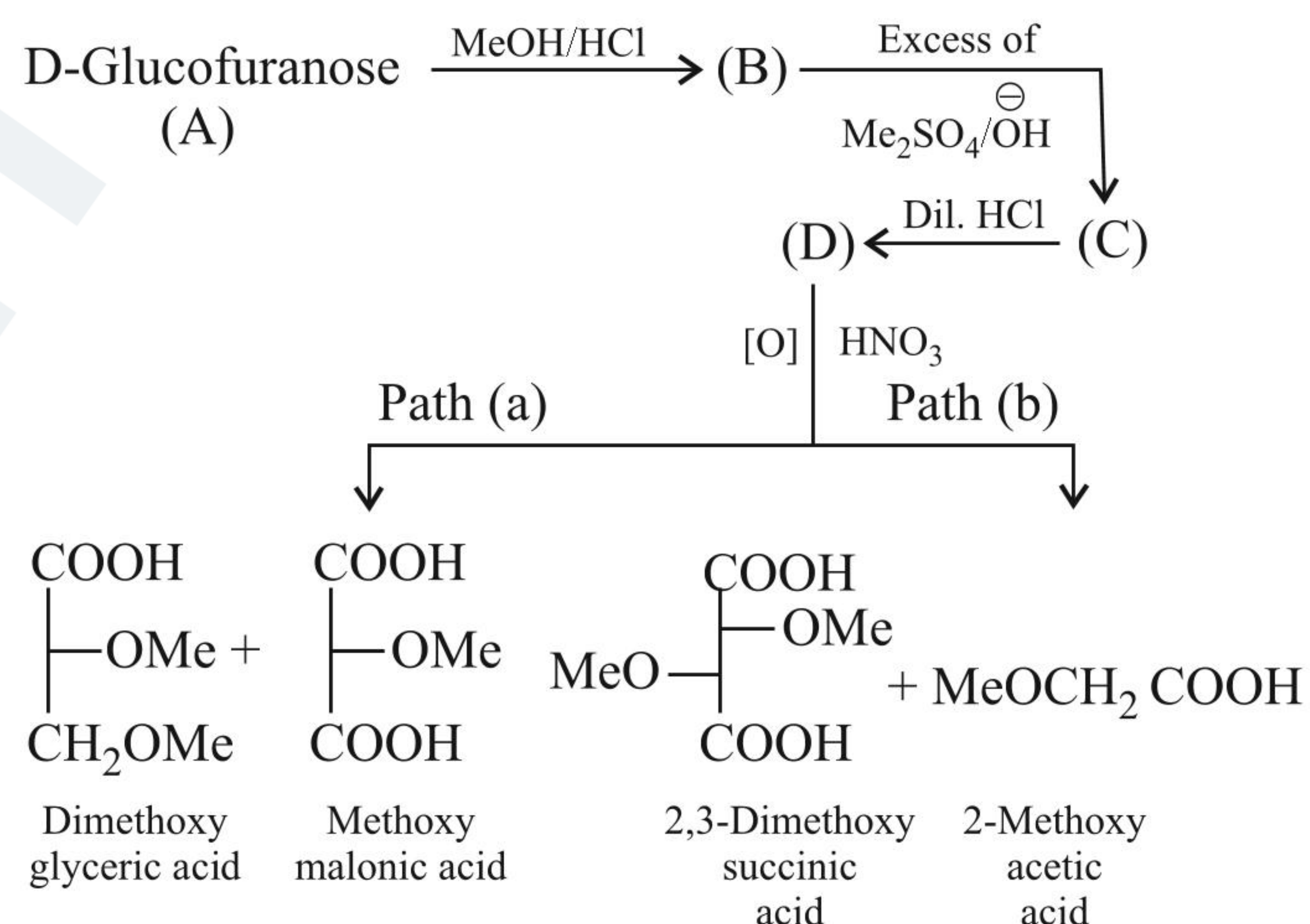
12. Compound (D) is:



13. Which statement(s) is/are correct about the products (E) and (F)?

- (1) The product (E) is obtained by the breakage of C-4 and C-5 bond of compound (D).
- (2) The product (E) is obtained by the breakage of C-5 and C-6 bond of compound (D).
- (3) The product (F) is obtained by the breakage of C-4 and C-5 bond of compound (D).
- (4) The product (F) is obtained by the breakage of C-5 and C-6 bond of compound (D).

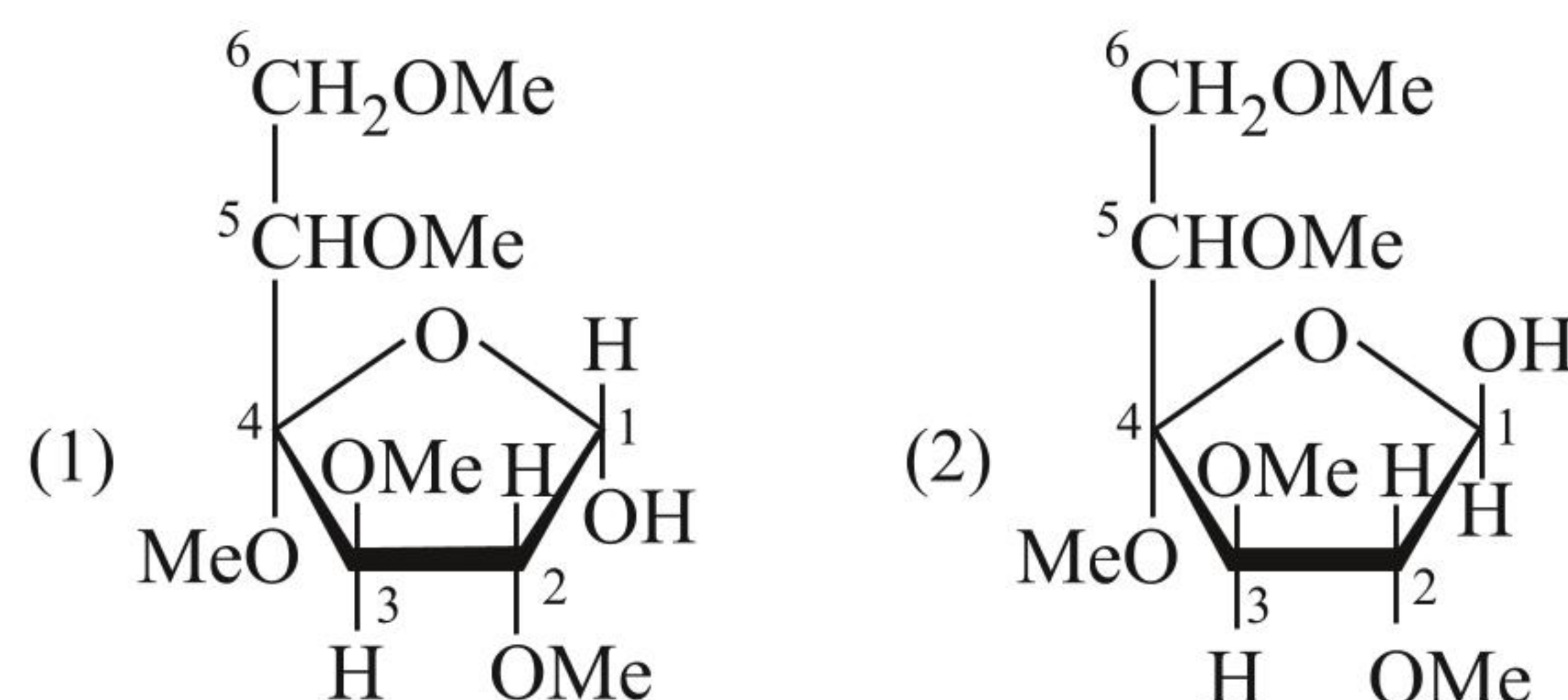
Paragraph 4

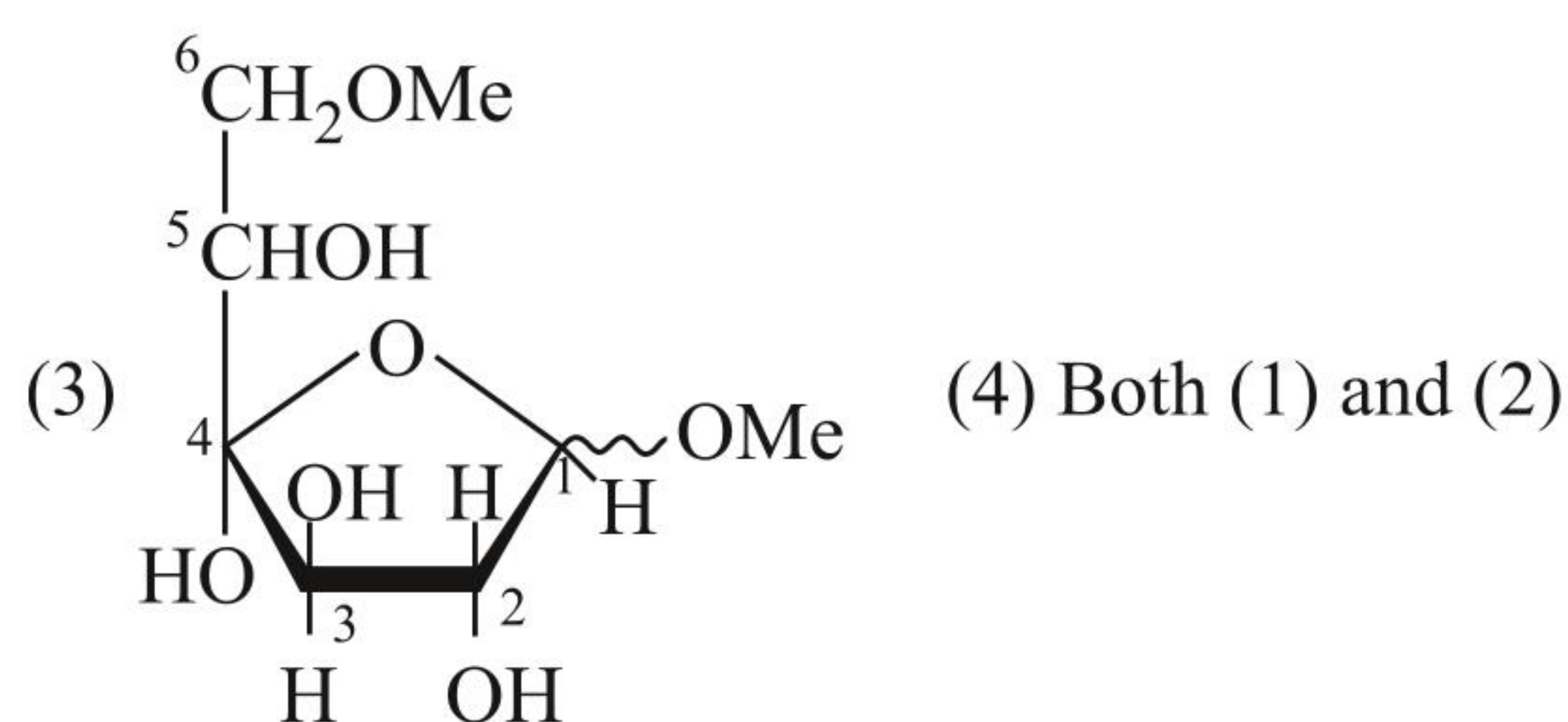


14. Which statement(s) is/are correct about (A)?

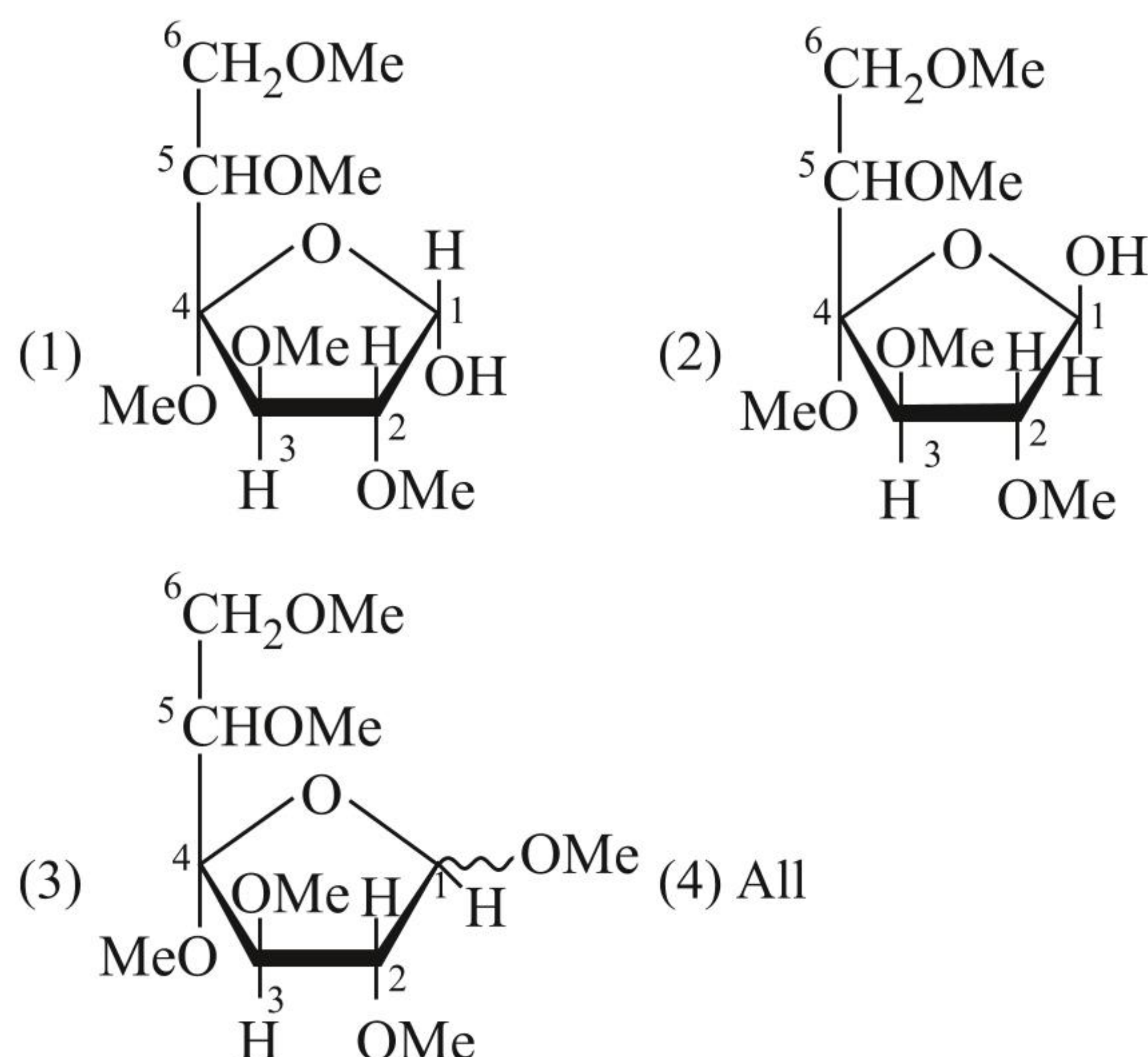
- (1) It contains an acetalic linkage.
- (2) It contains a hemiacetalic linkage.
- (3) It has a six-membered cyclic ring and a δ -hemi-acetalic linkage.
- (4) It has a five-membered cyclic ring and a γ -hemi-acetalic linkage.

15. Compound (B) is:

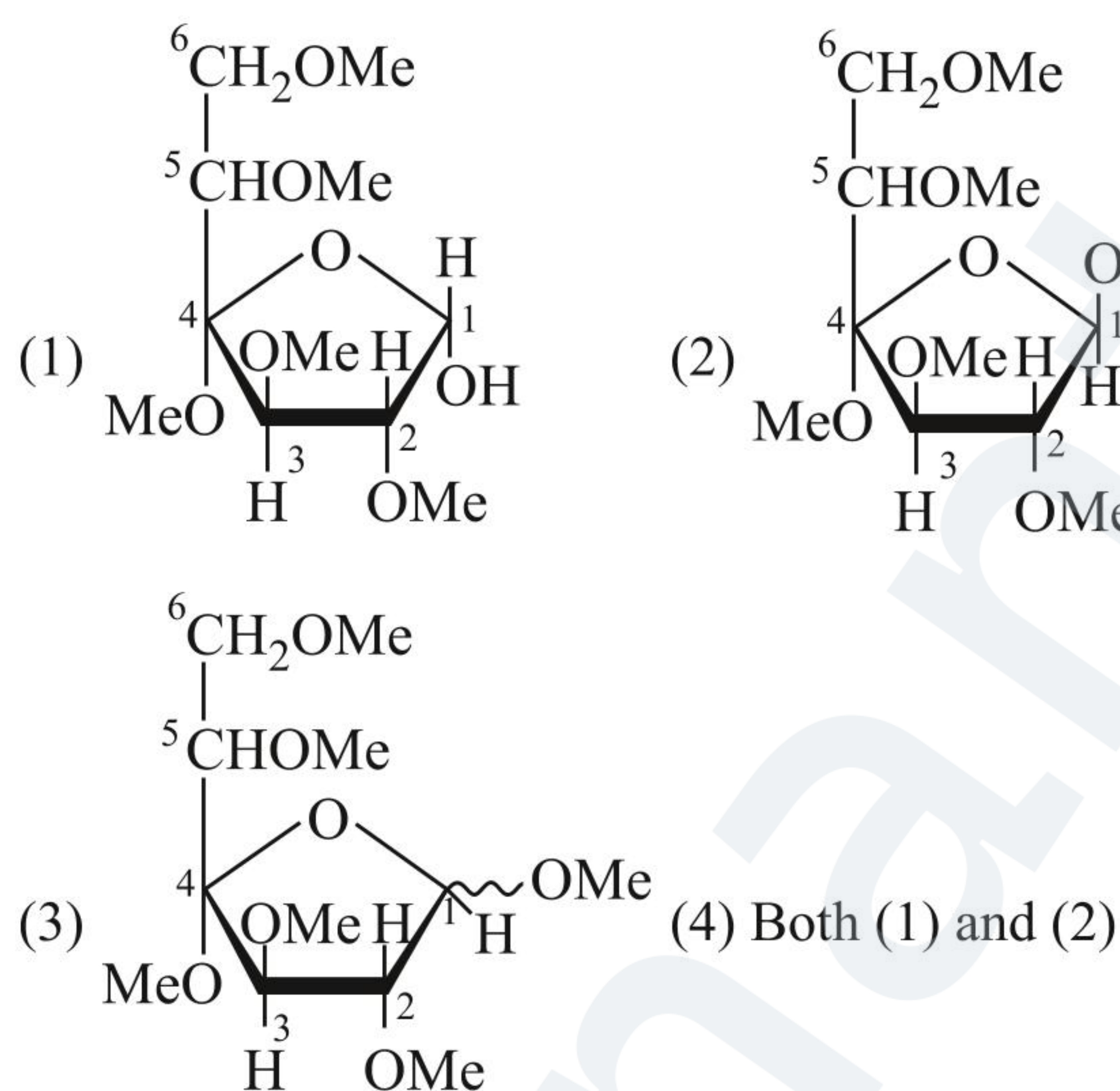




16. Compound (C) is:



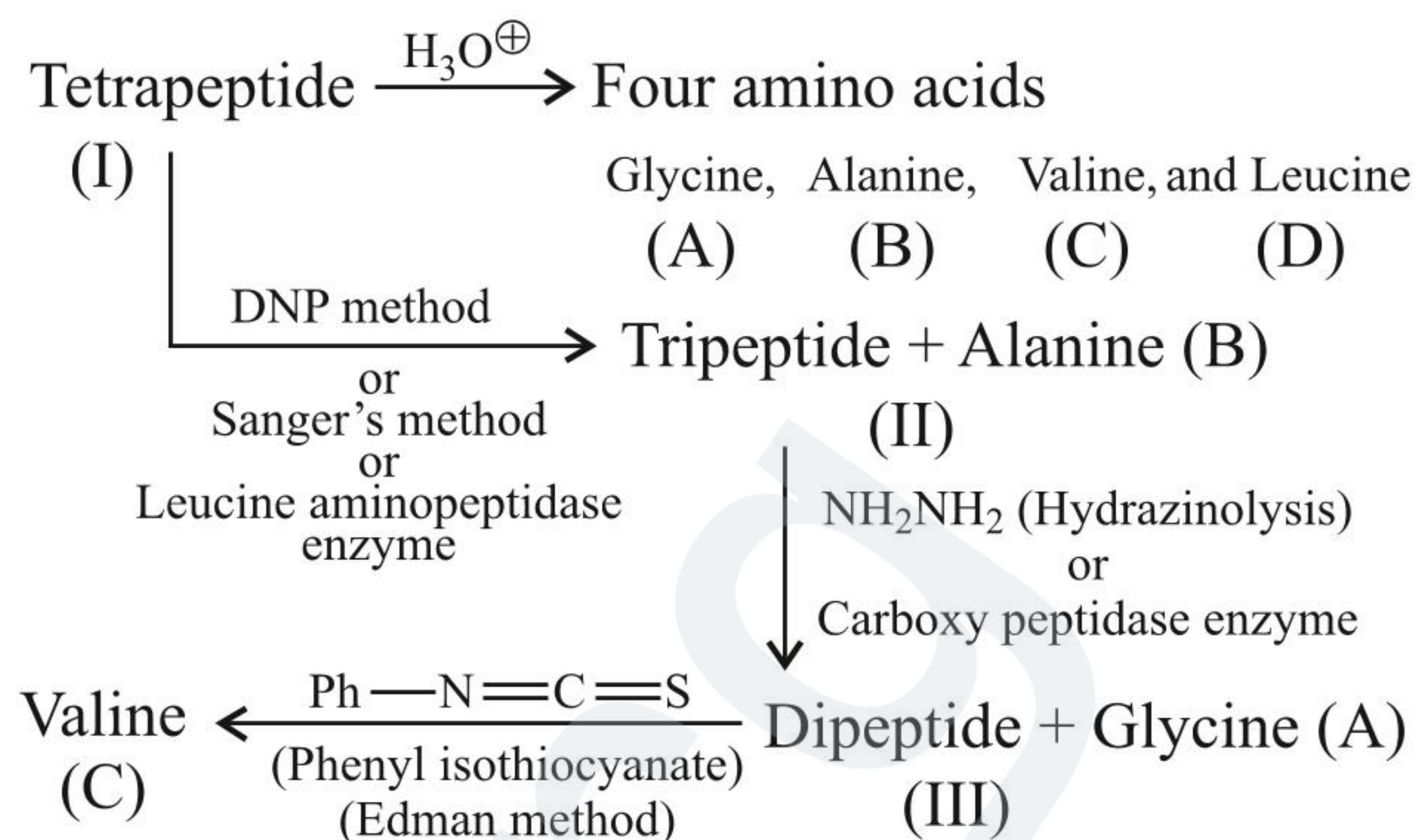
17. Compound (D) is:



18. Which statement(s) is/are correct about the products from (D) by path (a) and path (b)?

- (1) The products by path (a) are obtained by the breakage of C-3 and C-4 bond of compound (D).
- (2) The products by path (a) are obtained by the breakage of C-4 and C-5 bond of compound (D).
- (3) The products by path (b) are obtained by the breakage of C-3 and C-4 bond of compound (D).
- (4) The products by path (b) are obtained by the breakage of C-4 and C-5 bond of compound (D).

Paragraph 5



19. The dipeptide (III) is:

- (1) Val $\rightarrow$ Leu
- (2) Leu $\rightarrow$ Val
- (3) Gly $\rightarrow$ Ala
- (4) Ala $\rightarrow$ Gly

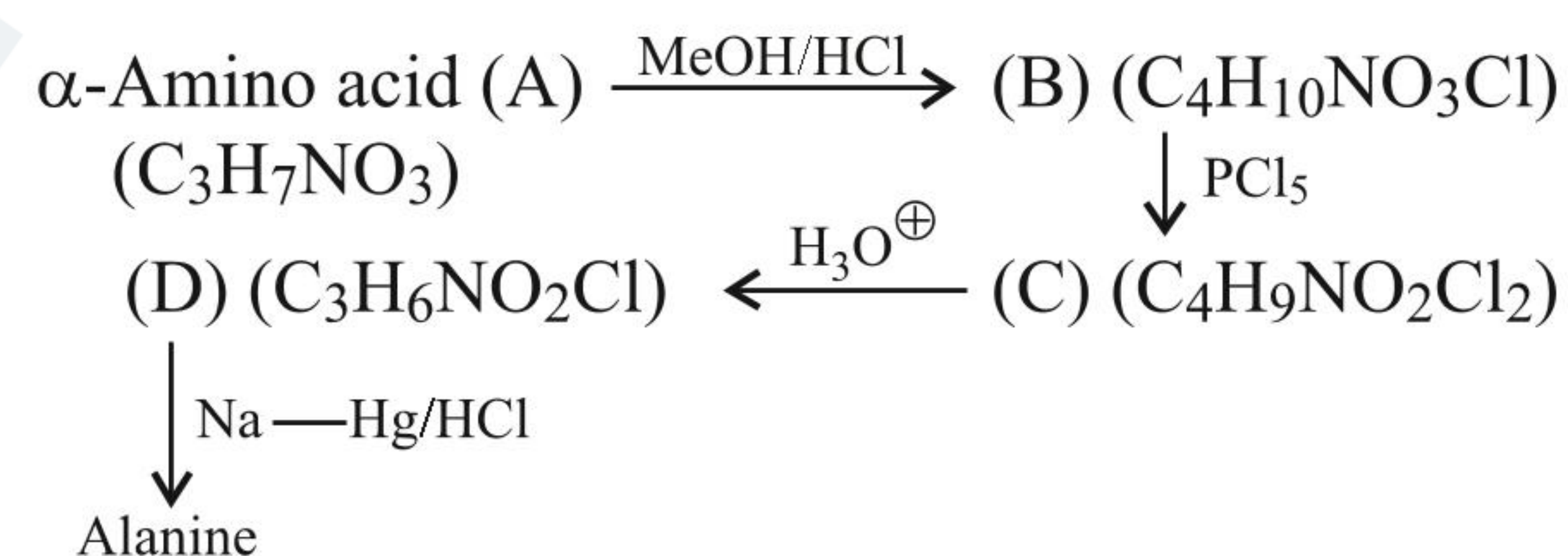
20. The tripeptide (II) is:

- (1) Gly $\rightarrow$ Leu $\rightarrow$ Val
- (2) Val $\rightarrow$ Leu $\rightarrow$ Gly
- (3) Leu $\rightarrow$ Gly $\rightarrow$ Val
- (4) Val $\rightarrow$ Gly $\rightarrow$ Leu

21. The tetrapeptide (I) is:

- (1) Gly $\rightarrow$ Leu $\rightarrow$ Val $\rightarrow$ Ala
- (2) Ala $\rightarrow$ Val $\rightarrow$ Gly $\rightarrow$ Leu
- (3) Gly $\rightarrow$ Val $\rightarrow$ Leu $\rightarrow$ Ala
- (4) Ala $\rightarrow$ Val $\rightarrow$ Leu $\rightarrow$ Gly

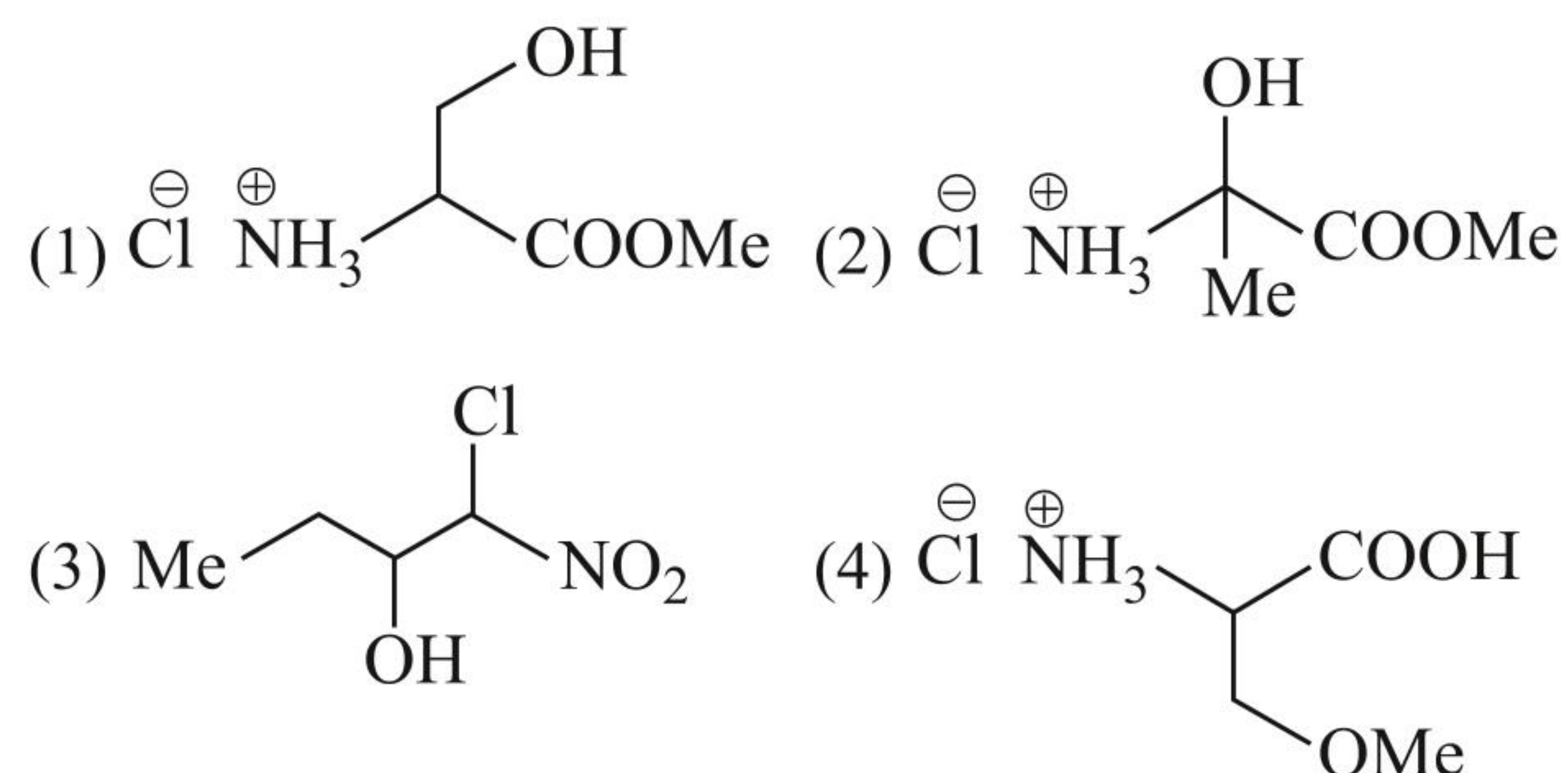
Paragraph 6



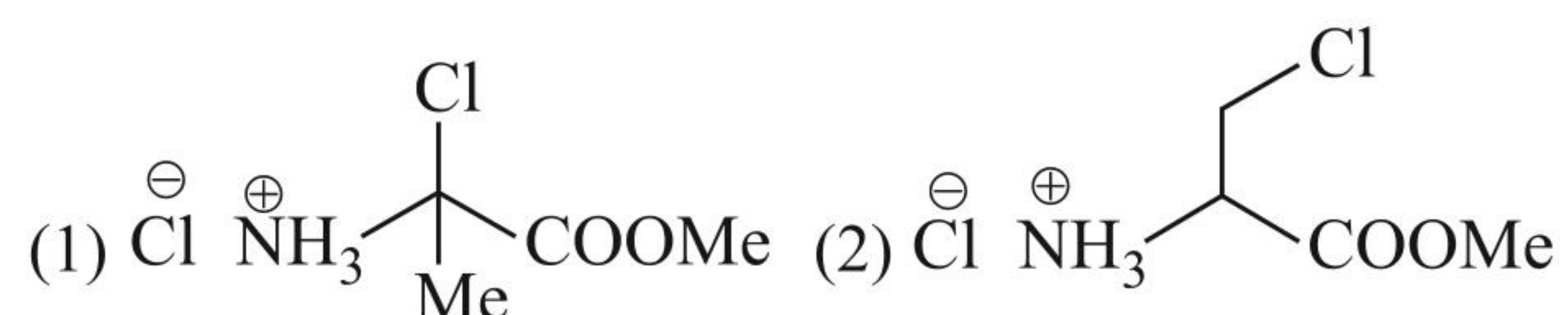
22. Compound 'A' has many functional groups.

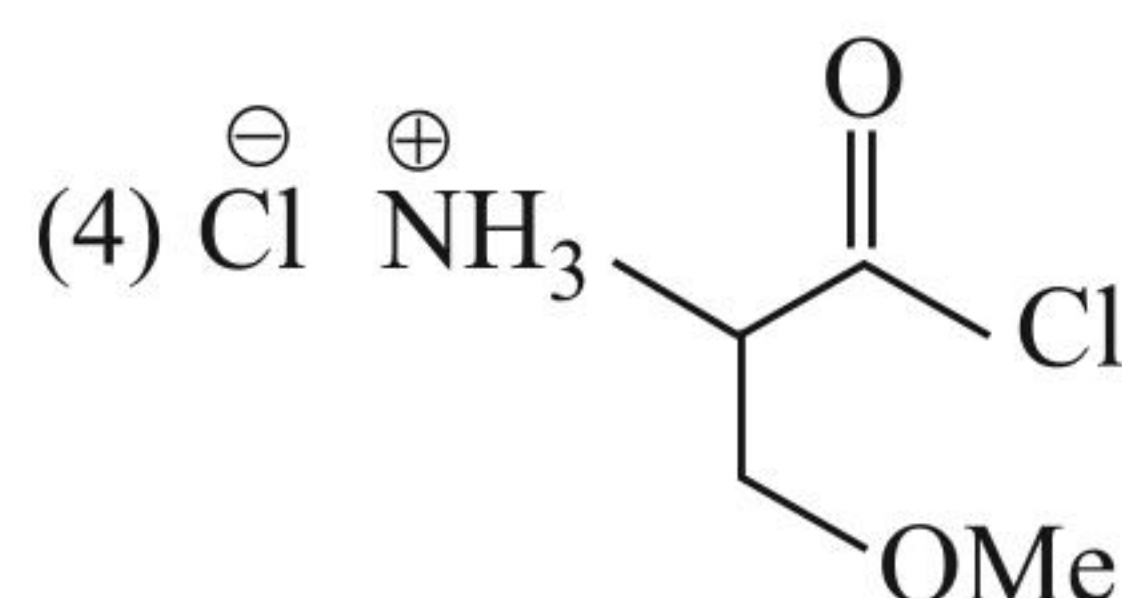
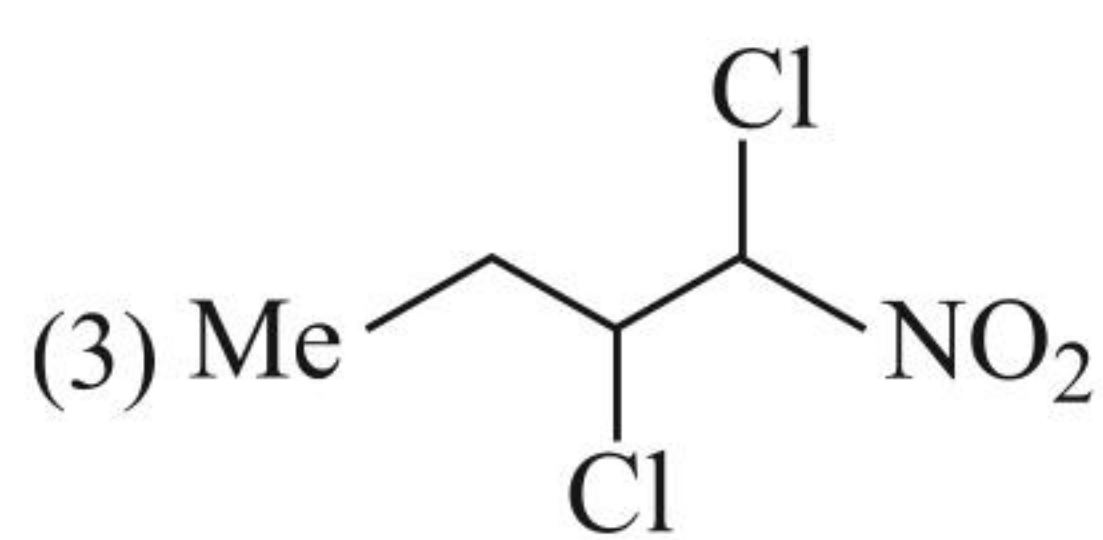
- (1) 1
- (2) 2
- (3) 3
- (4) 4

23. Compound (B) is:

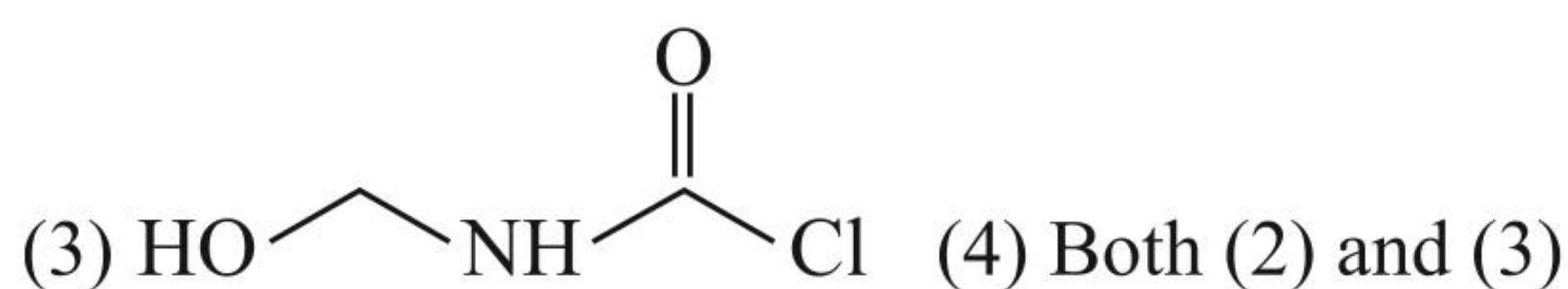
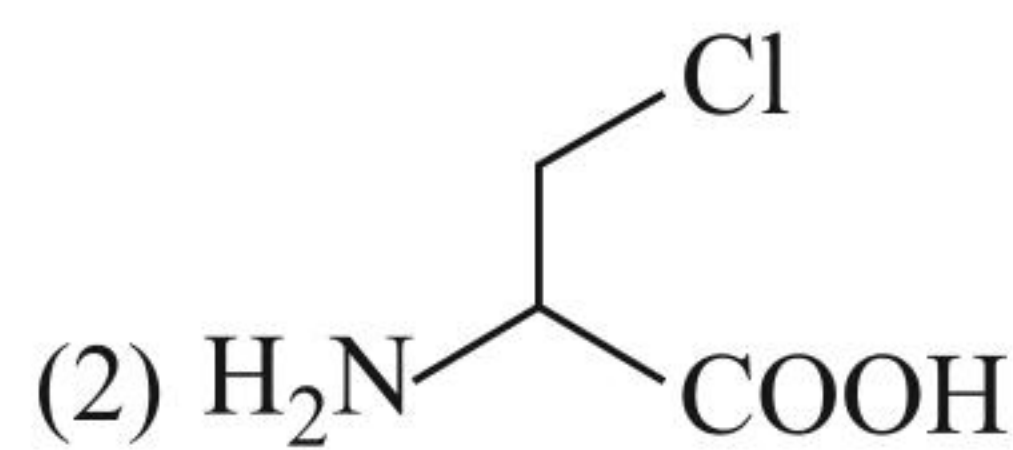
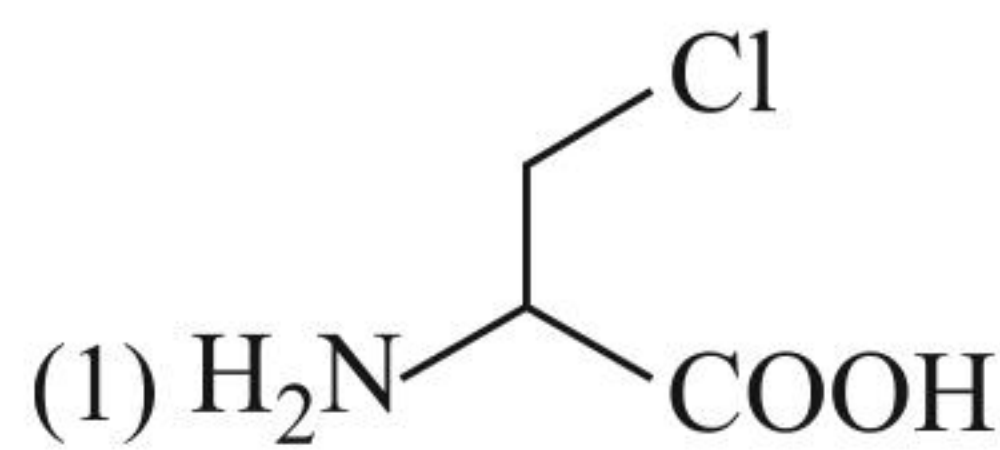


24. Compound (C) is:



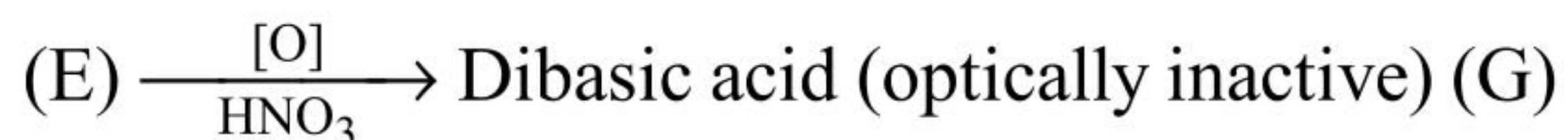
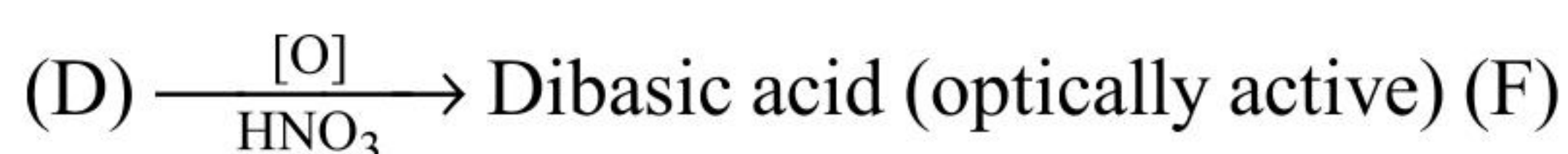
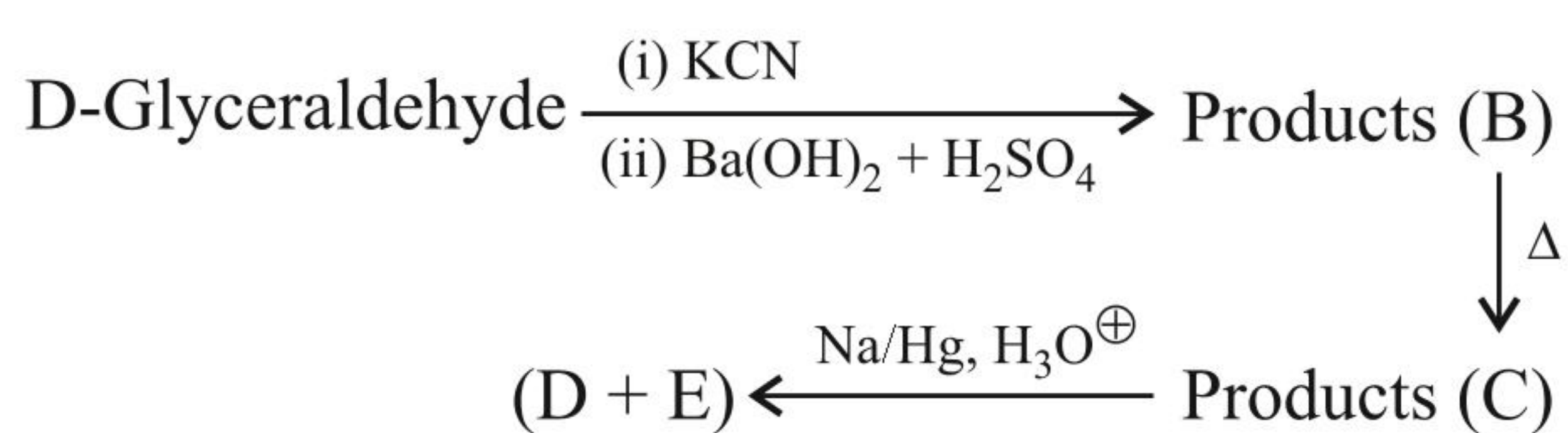


25. Compound (D) is:



(4) Both (2) and (3)

Paragraph 7



26. Two isomeric products are obtained in (B). They are:

- (1) Diastereomers (2) Anomers
(3) C-2 epimer (4) C-3 epimer

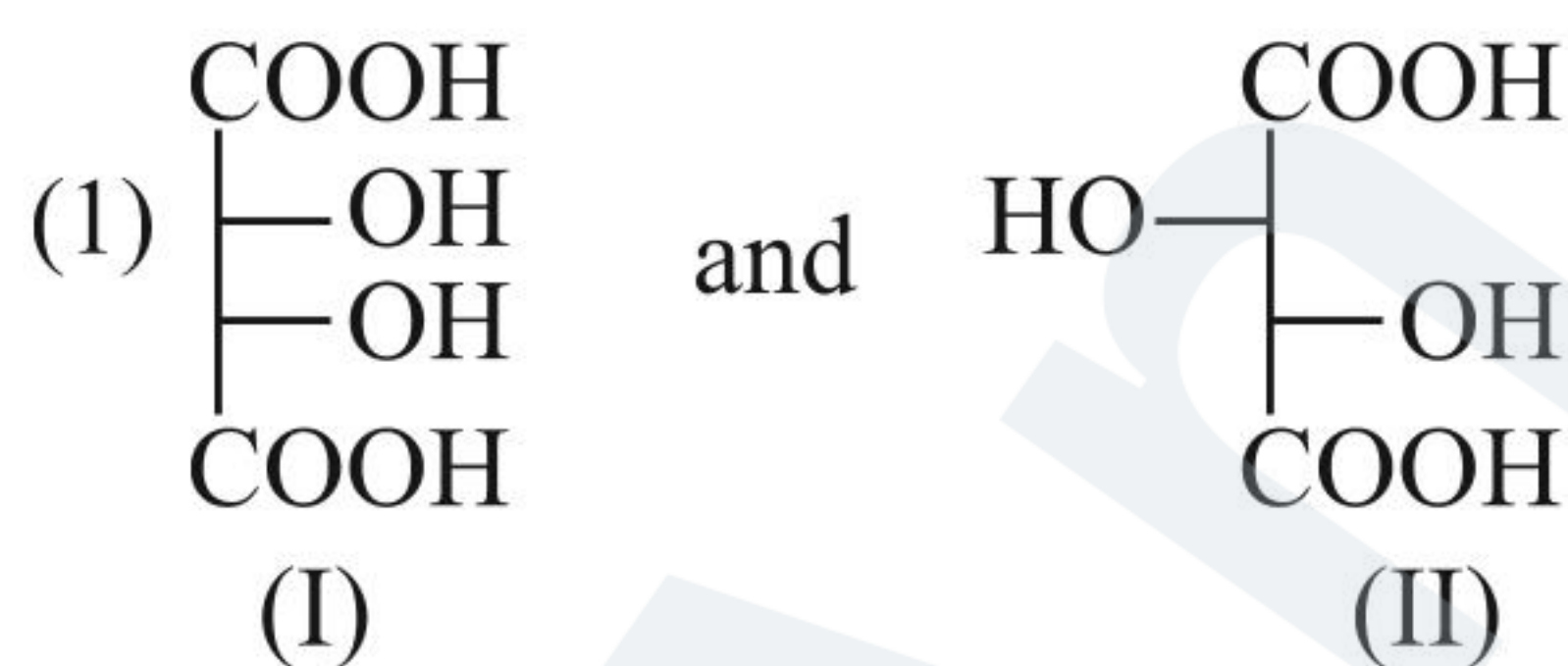
27. The sequence from (A) to (D + E) is called:

- (1) Wohl's method (2) Ruff method
(3) Kiliani's method (4) Ekenstein method

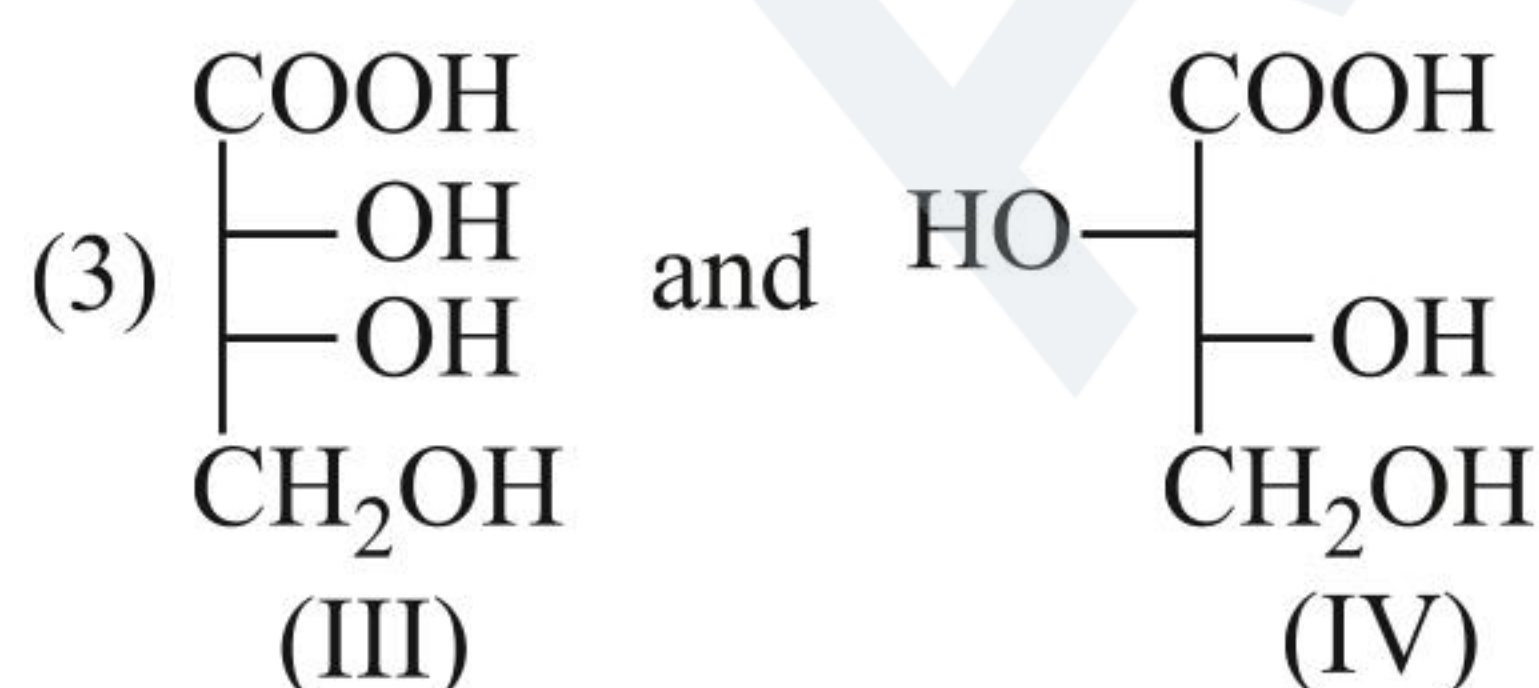
28. Two isomeric products are obtained in (C) They are:

- (1) Both γ -lactones (2) Both δ -lactones
(3) One is γ -lactone and another is δ -lactone
(4) None

29. The compounds (F) and (G), respectively, are:



(2) (II) and (I)



(4) (IV) and (III)

Matrix Match Type

Match the compounds in column I with their characteristic(s)/test(s)/reaction(s)/reagent(s)/stereochemistry/isomer(s) given in column II. Matching can be one or more than one.

1.

S. No.	Column I Compound	Column II Reagents/reactions
a.	D-Glucose	p. Mutarotation
b.	D-Fructose	q. $[\text{Cu}(\text{NH}_3)_4]^{+2} (\text{OH})_2$ + Tartarate ion
c.	Sucrose	r. $[\text{Ag}(\text{NH}_3)_2]^{\oplus} \text{OH}^{\ominus}$
d.	Lactose	s. $[\text{Cu}(\text{NH}_3)_4]^{2+} (\text{OH})_2$ + Citrate ion
e.	Maltose	t. Schiff's reagent
f.	Hexanal	u. Maltase

2.

S. No.	Column I Compound	Column II Linkage
a.	Sucrose	p. $(\text{C}_1-\alpha)$ of glucose $\rightarrow$ C_4 of glucose
b.	Maltose	q. $(\text{C}_1-\alpha)$ of glucose $\rightarrow$ C_4 of glucose and $(\text{C}_1-\alpha)$ of glucose $\rightarrow$ C_6 of glucose in another chain
c.	Lactose	r. $(\text{C}_1-\beta)$ of glucose $\rightarrow$ C_4 of glucose
d.	Starch	s. $(\text{C}_1-\beta)$ of galactose $\rightarrow$ C_4 of glucose
e.	Cellulose	t. $(\text{C}_1-\alpha)$ of glucose $\rightarrow$ $(\text{C}_2-\beta)$ of fructose

3.

S. No.	Column I Compound	Column II Anomer
a.	β -L (-) Glucopyranose	p. α -D (-) fructofuranose
b.	β -D (+) Glucofuranose	q. α -D (-) fructopyranose
c.	β -D (-) Fructofuranose	r. α -L (-) glucopyranose
d.	β -D (-) Fructopyranose	s. α -D (+) glucofuranose

4.

S. No.	Column I Structure of protein	Column II Characteristic property
a.	α -Helix structure	p. The polypeptide chains lie side by side in an open structure having inter-chain amide H-bonding that holds the chains together.
b.	β -Pleated sheet structure	q. The polypeptide chain is coiled up into a right handed spiral structure. It is stabilised by intra-molecular H-bonding between (C=O) of one amino acid residue and the (N—H) of the 4th AA residue in the chain. This is also called 3.6 ₁₃ helix, having 3.6 AA in each turn of the helix and 13- membered ring.

c.	Parallel pleated sheet structure	r. This structure has the chains running in opposite directions. The α -C atoms rotate slightly out of the plane of the sheet to minimise repulsions between their bulky (R) groups.
d.	Anti-parallel pleated sheet structure	s. This structure has chains running in the same direction; all with their N-terminal residue starting at the same end. The (R) groups alternate positions below and above the sheet.

5.

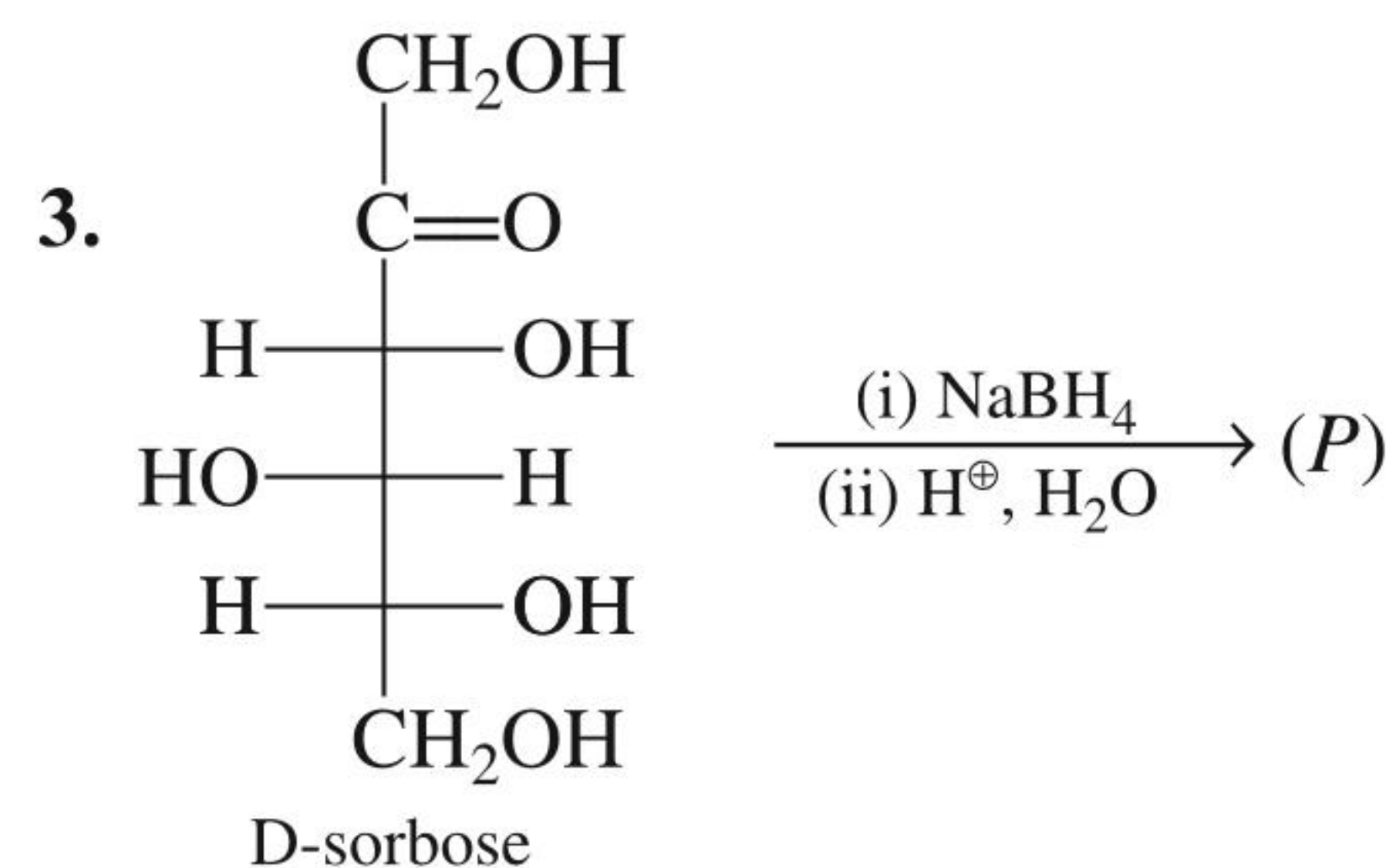
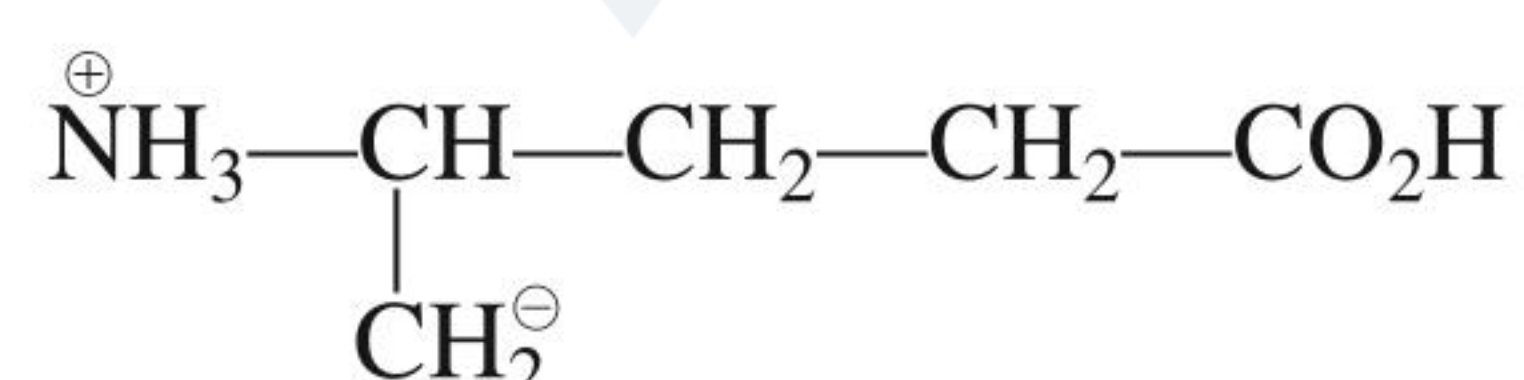
	Statements		Characteristics - I		Characteristics - II
a	α -D-glucopyranose	i	Do not give red ppt with an alkaline solution of CuSO_4 containing sodium citrate	p	Cyclic hemiacetal
b	Methyl- α -D-glucopyranoside	ii	Anomers	q	Cyclic acetal
c	α -D (–) and β -D (–) fructose	iii	Change in configuration of (OH) group at C-3	r	Diastereomers that differ in the configuration at the acetal or hemiacetal C-atom of a sugar in its cyclic form
d	α -D (+) glucose and α -D (+) allose	iv	Gives silver mirror with $[\text{Ag}(\text{NH}_3)_2]^+ \text{OH}^-$	s	Diastereomers with more than one stereocentre that differ in the configuration about only at one stereocentre
		v	Stereo chemistry at C-3, C-4 and C-5 in both is same	t	Same osazone

Numerical Value Type

1. How many compound which is given below is isomer of D-Glucose?

a. D-Mannose, b. D-Fructose, c. D-Glucose, d. D-Indoes, e. D-Galactose, f. D-Arabinose, g. D-Ribose.

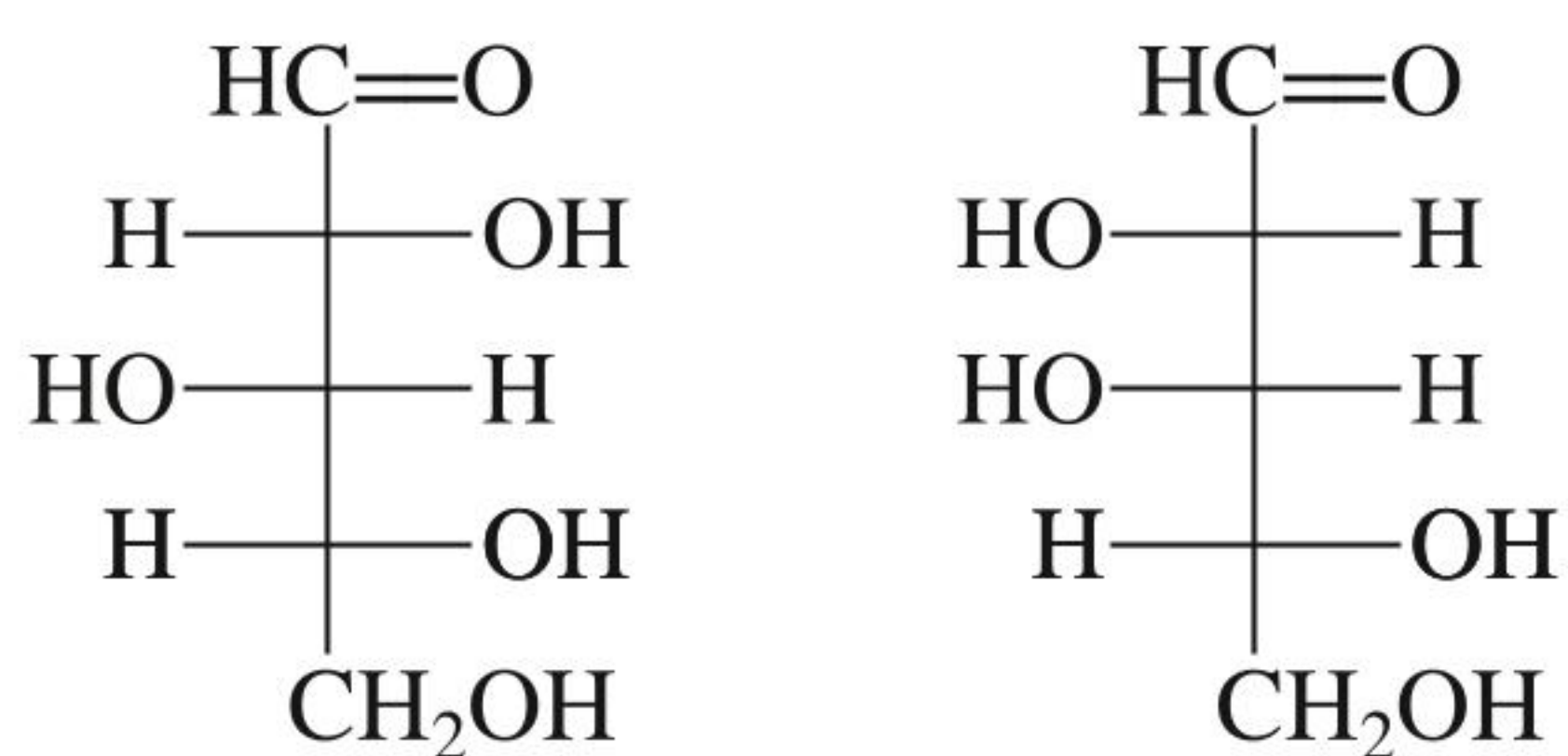
2. How many acidic group is present in given amino acid?



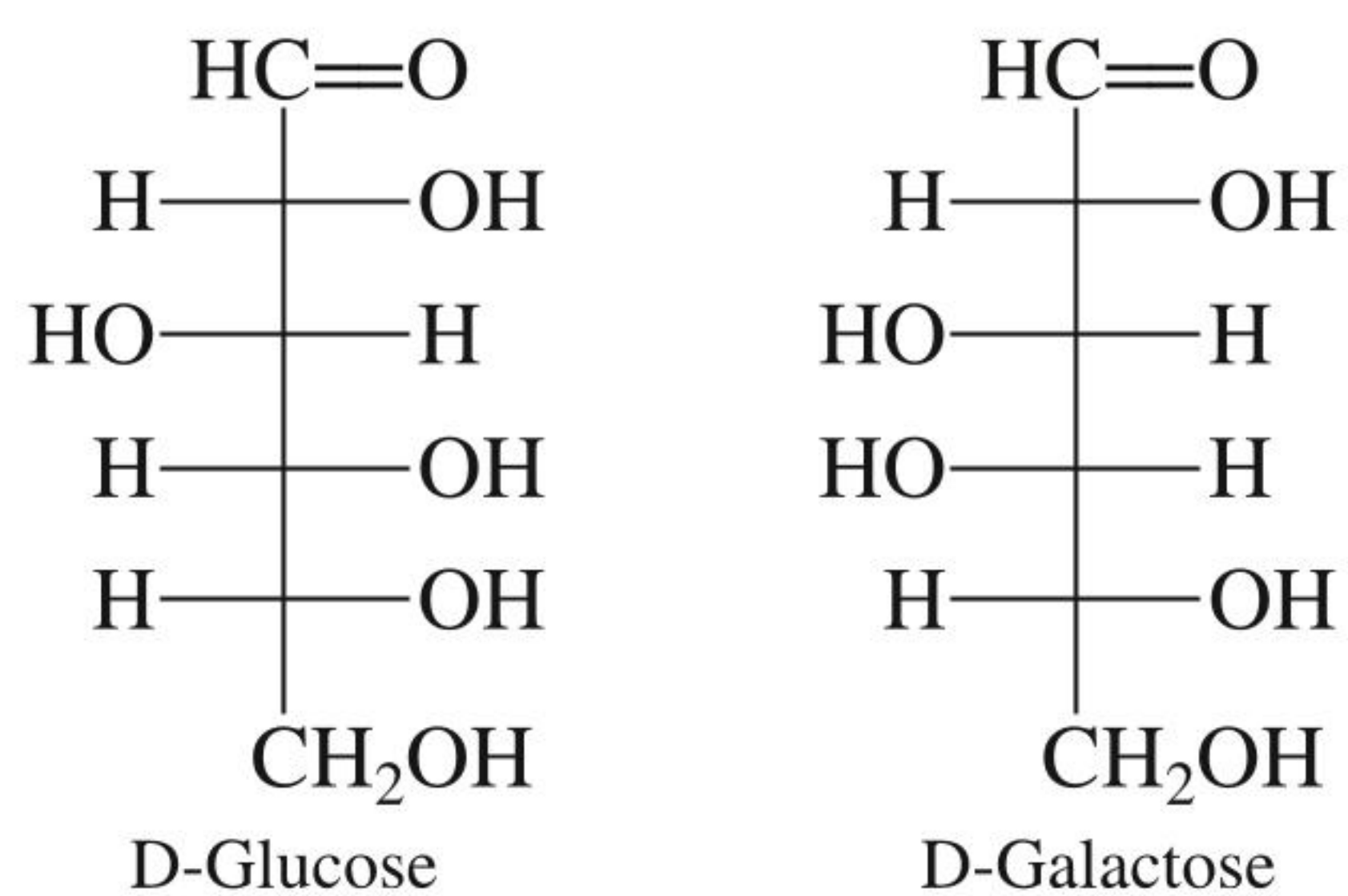
Number of stereoisomer of product (P) is:

- A triglyceride can have how many different acyl groups?
- In aqueous solution glucose exist in how many isomeric forms?
- Glucose molecule reacts with 'X' number of molecule of phenylhydrazine to yield osazone. The value of X is:

7. The number of Stereogenic centers in α -D-Glucose are:
 8. At which carbon are the following sugars epimers of each other?

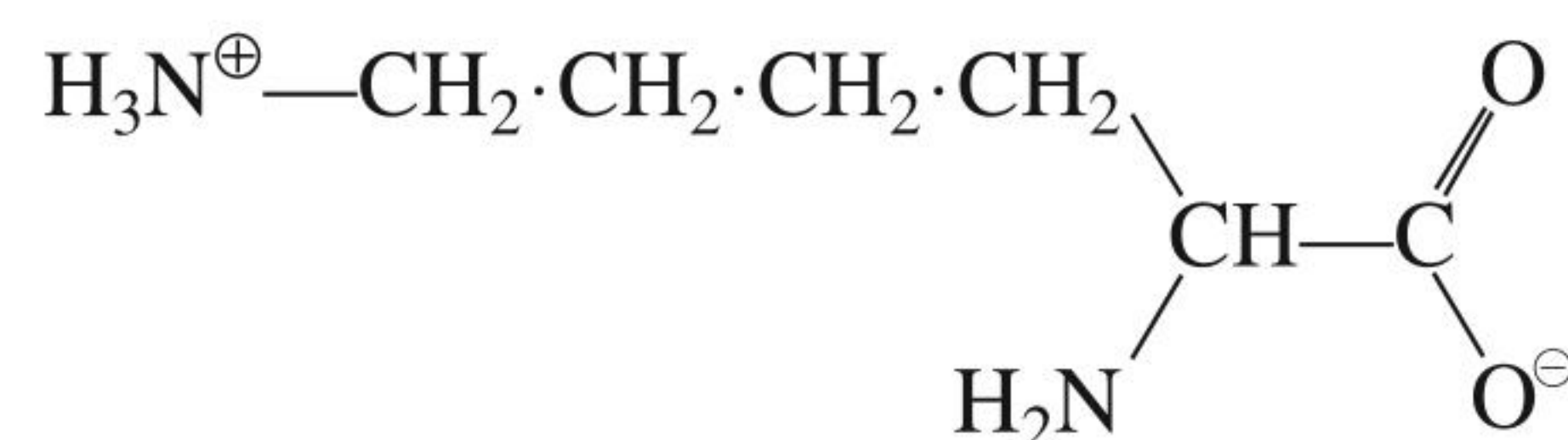


9. At which carbon are the following sugars epimers of each other?



10. How many chirality centers are there in an aldohexose?
 11. How many chirality centers are there in a 2-ketohexose?
 12. How many stereoisomers are possible for a 2-ketohexose?

13. What is the total number of basic groups in the following form of lysine?



14. $\text{OHC}(\text{CHOH})_4\text{CH}_2\text{OH}$
 $\downarrow \text{HIO}_4$

16-isomer of above compound when reacts with periodic acid (HIO_4). Calculate the value of X, when X is:

$$X = \frac{\text{No. of moles of HIO}_4 \text{ consumed}}{10}$$

15. The value of X for a 2-ketoheptose, when X is

$$X = \frac{\text{No. of stereoisomers}}{8}$$

16. The value of X for an aldohexose, when X is

$$X = \frac{\text{No. of stereoisomers}}{8}$$

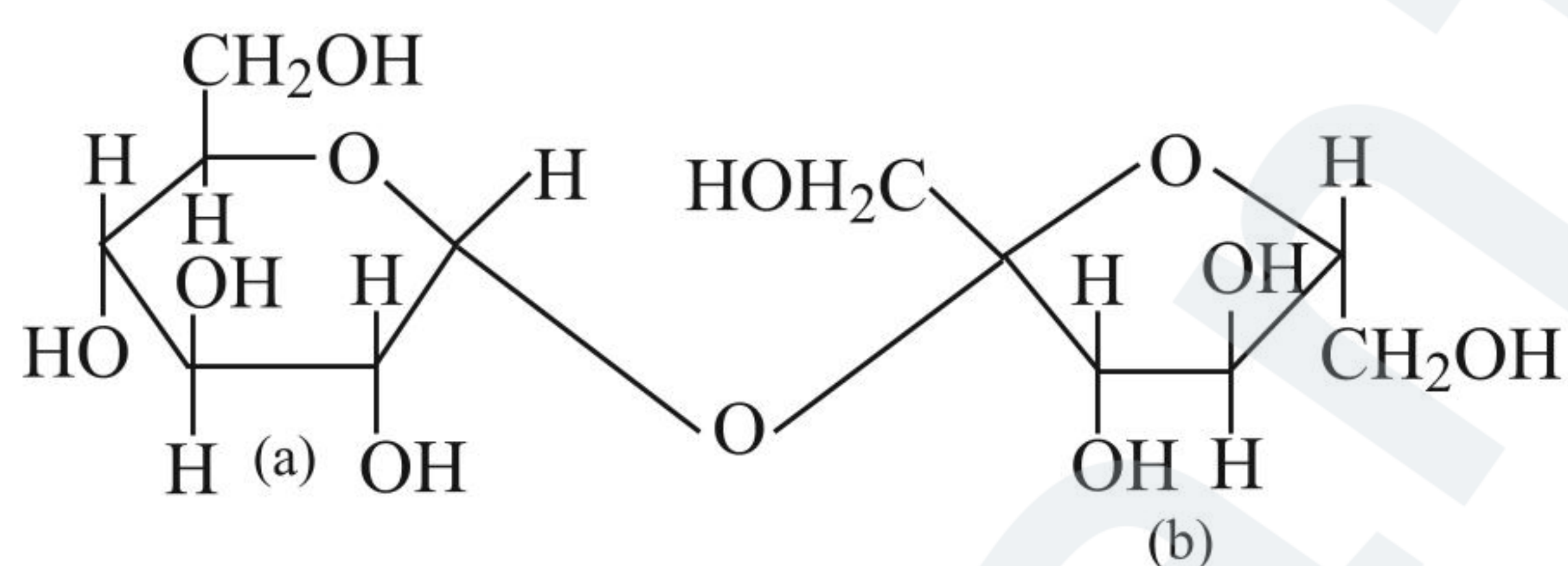
17. No. of stereoisomers for a ketotriose is:

Archives

JEE ADVANCED

Single Correct Answer Type

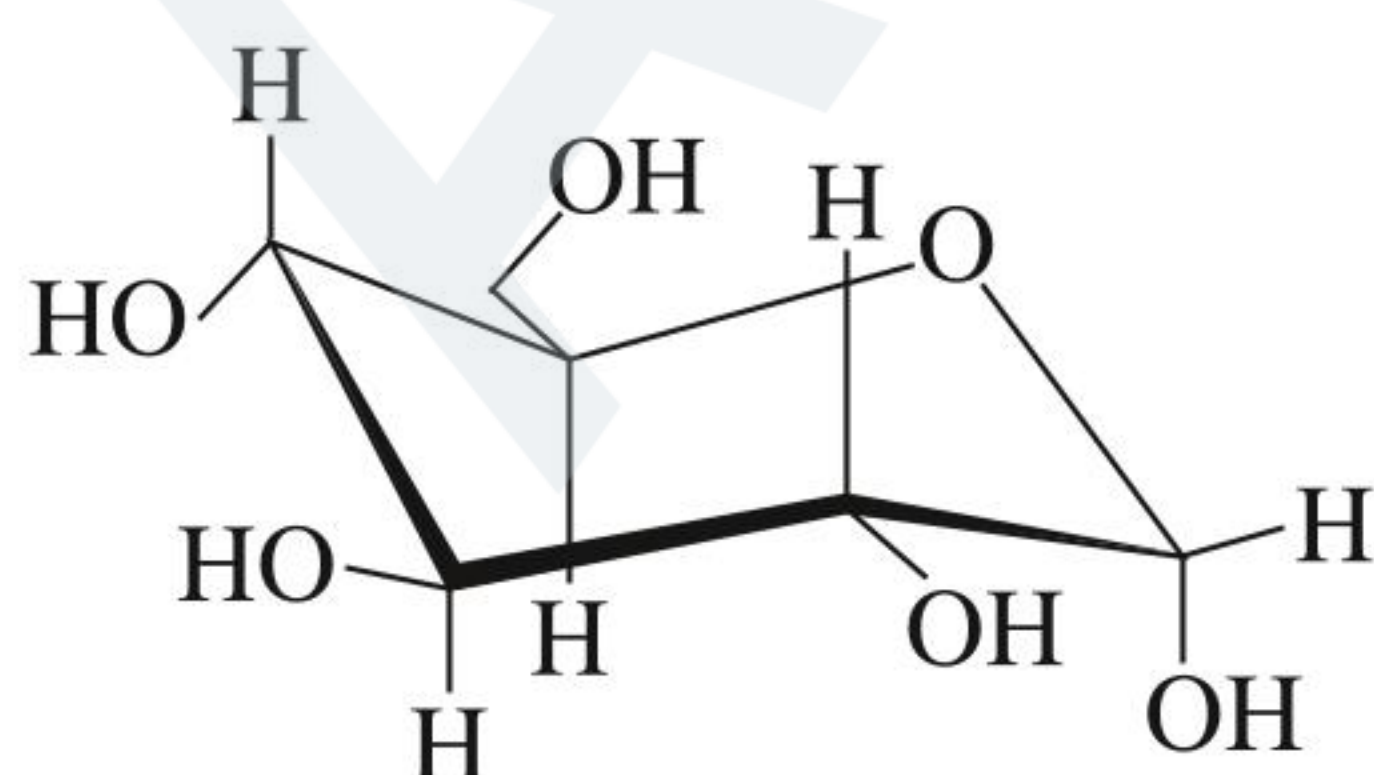
1. The correct statement about the following disaccharide is:



- (1) Ring (a) is pyranose with α -glycosidic link.
 (2) Ring (a) is furanose with α -glycosidic link.
 (3) Ring (b) is furanose with α -glycosidic link.
 (4) Ring (b) is pyranose with β -glycosidic link.

(IIT-JEE 2010)

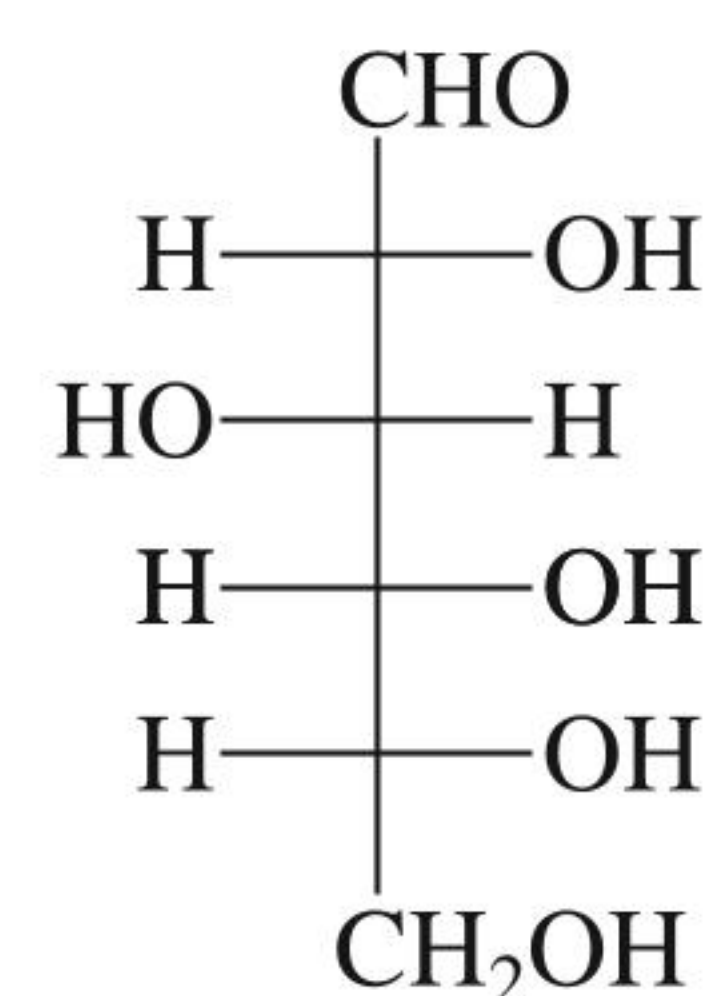
2. The following carbohydrate is



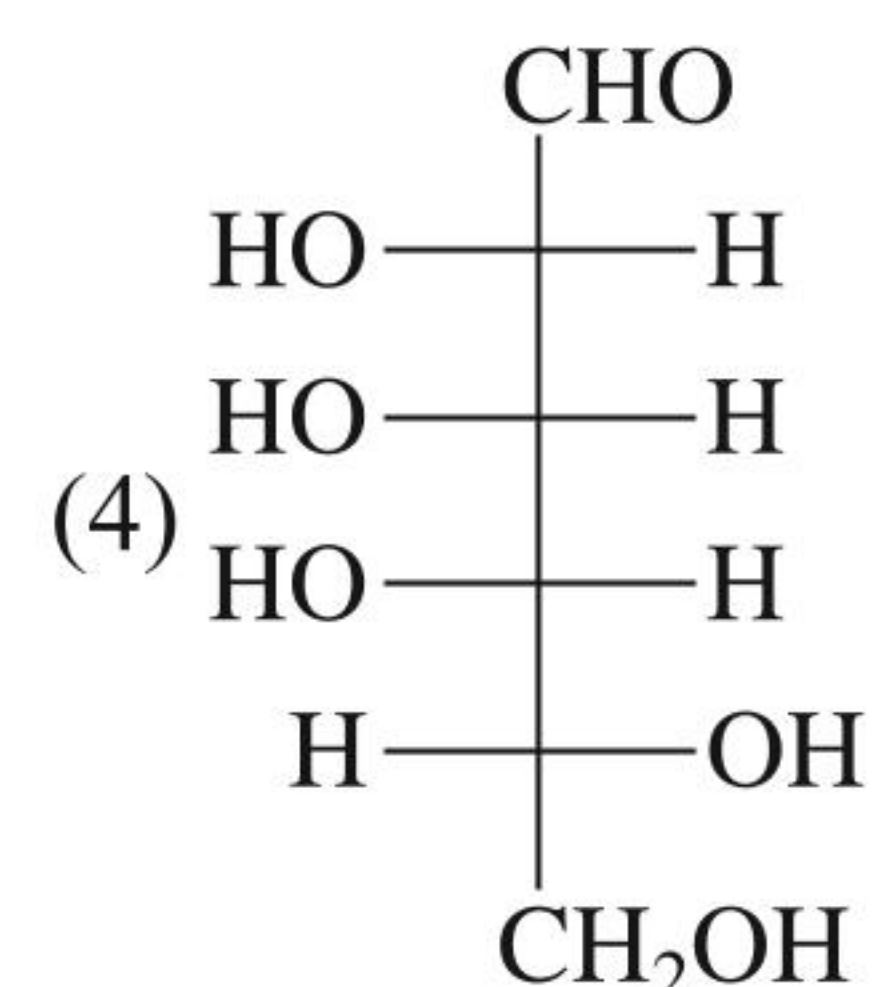
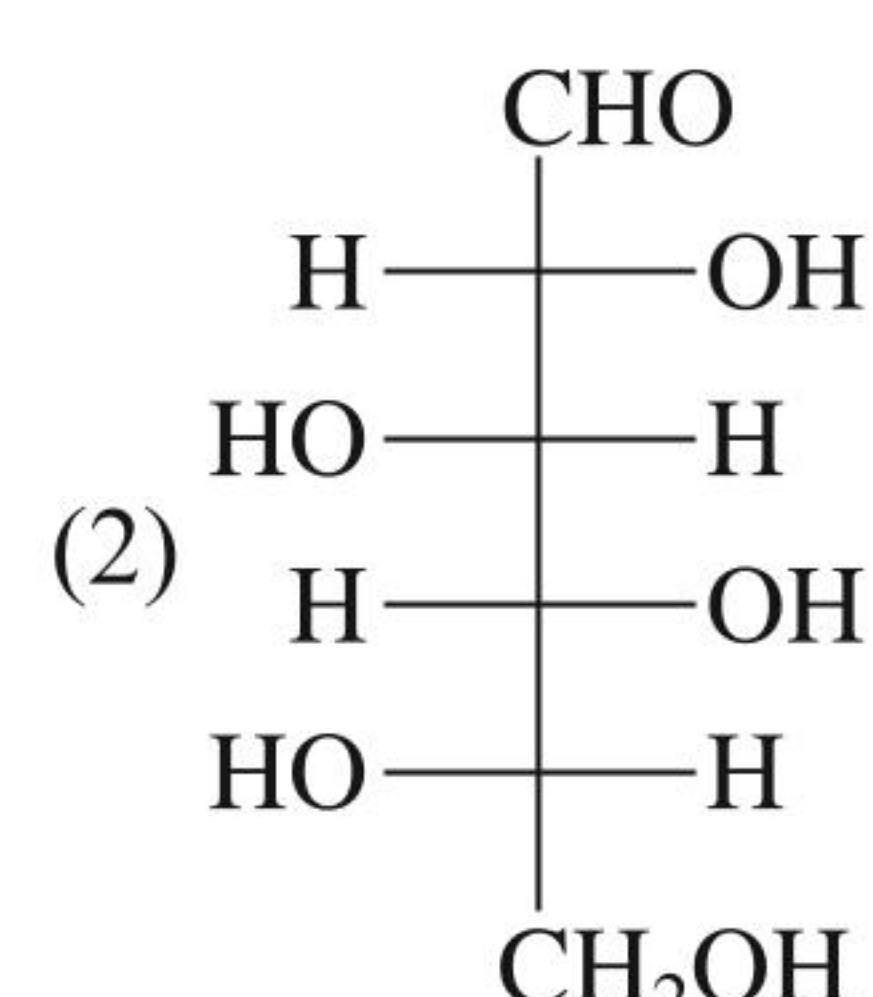
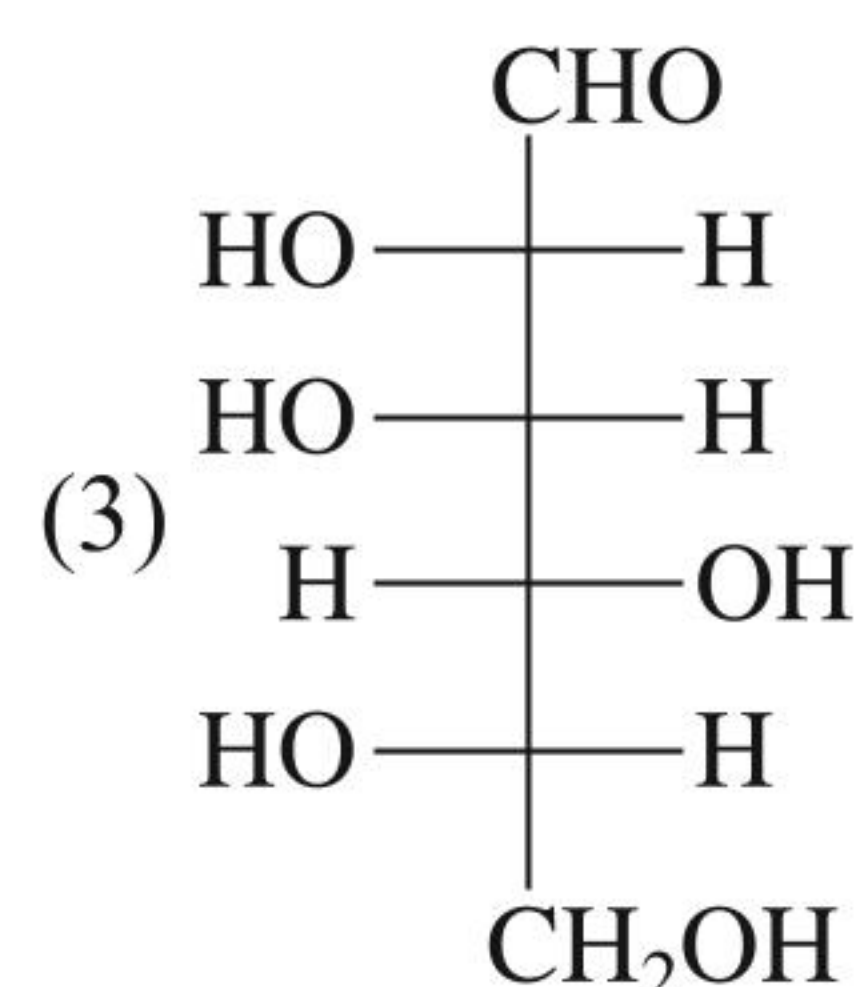
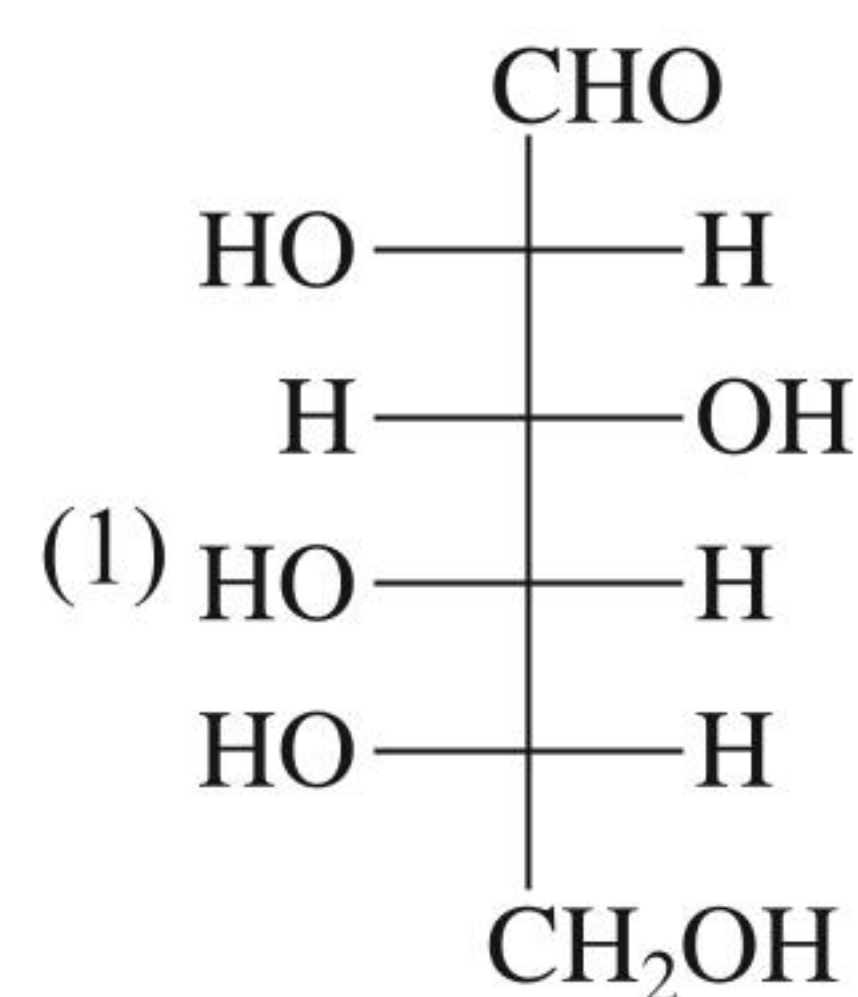
- (1) a ketohexose (2) an aldohexose
 (3) an α -furanose (4) an α -pyranose

(IIT-JEE 2011)

3. The structure of D-(+)-glucose is



The structure of L-(-)-glucose is



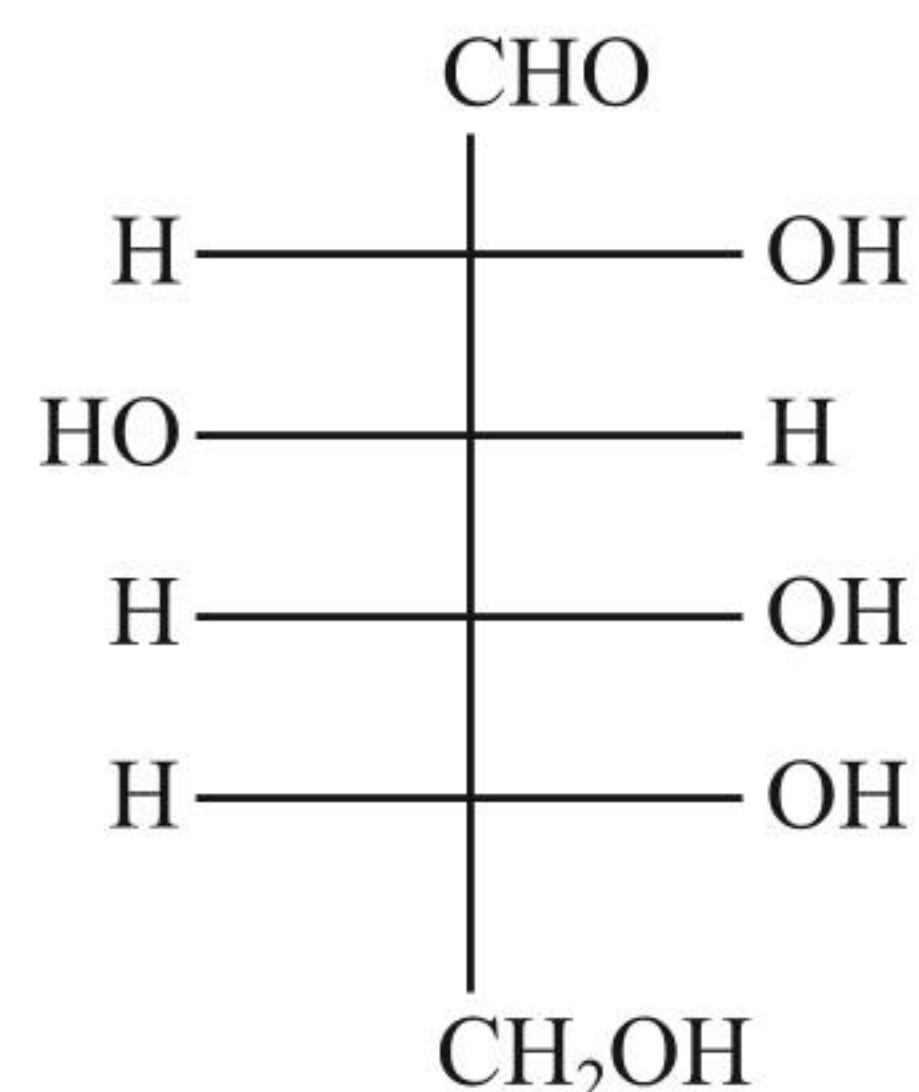
(JEE Advanced 2015)

4. Complete hydrolysis of starch gives:

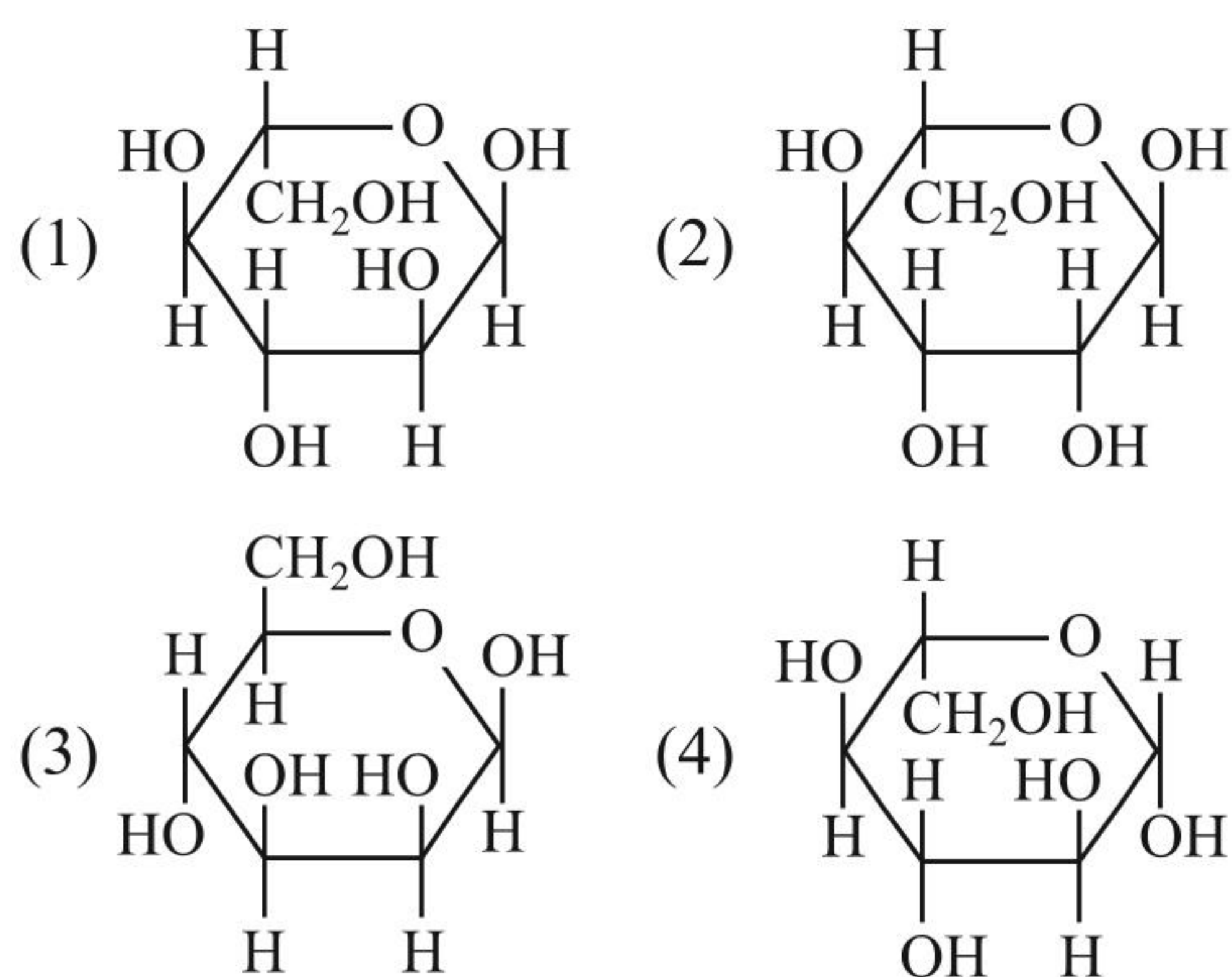
- (1) glucose and fructose in equimolar amounts
- (2) galactose and fructose in equimolar amounts
- (3) glucose only
- (4) glucose and galactose in equimolar amounts

(JEE Advanced 2015)

5. The Fischer presentation of *D*-glucose is given below



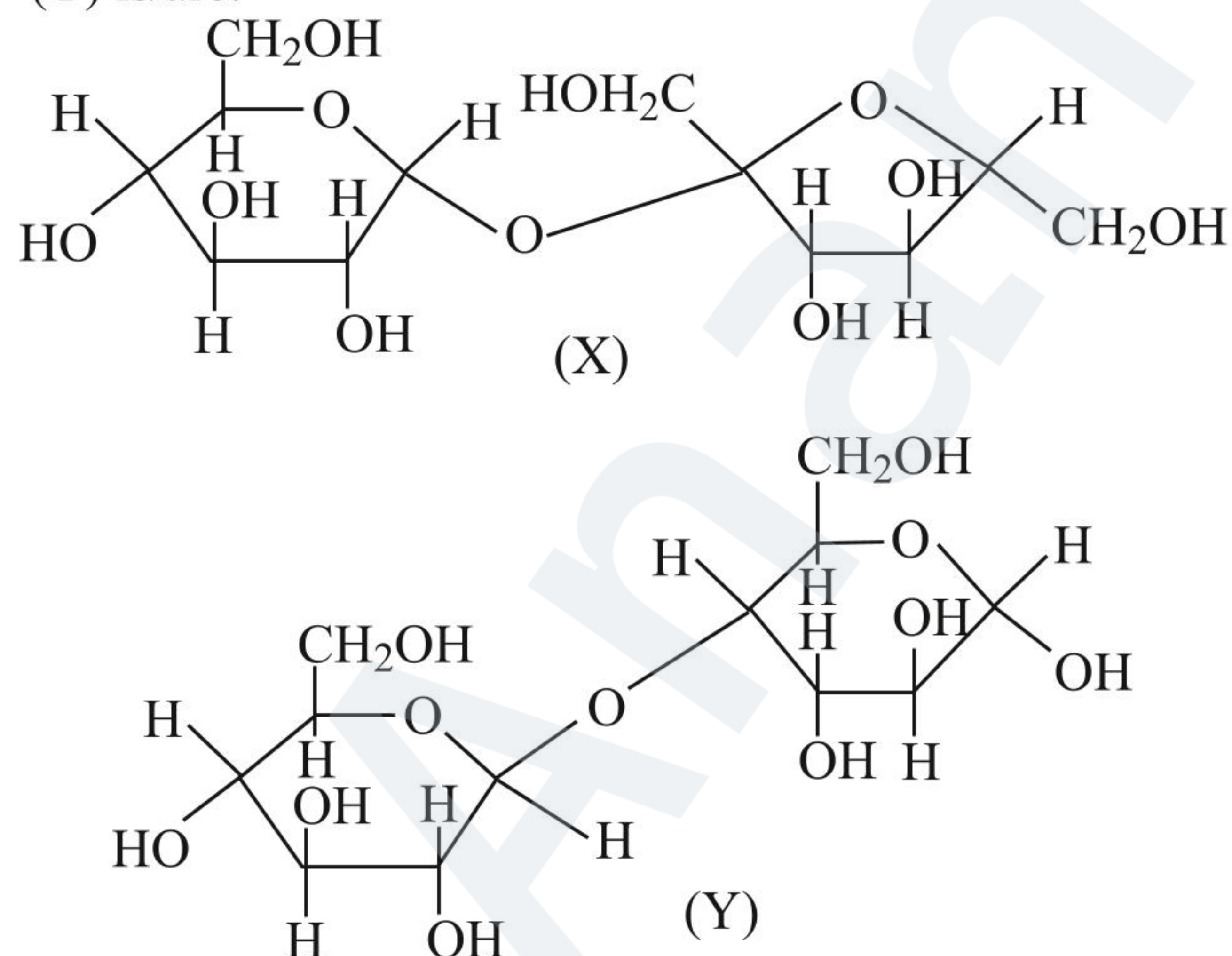
The correct structures(s) of β -*L*-glucopyranose is(are)



(JEE Advanced 2018)

Multiple Correct Answers Type

1. The correct statement(s) about the following sugars (X) and (Y) is/are:



- (1) (X) is a reducing sugar and (Y) is a non-reducing sugar.
- (2) (X) is a non-reducing sugar and (Y) is a reducing sugar.
- (3) The glucosidic linkages in (X) and (Y) are α and β , respectively.
- (4) The glucosidic linkages in (X) and (Y) are β and α , respectively.

(IIT-JEE 2009)

2. For 'invert sugar', the correct statement(s) is (are)

(Given: specific rotations of (+)-sucrose, (+)-maltose, L-(−)glucose and L (+)-fructose in aqueous solution are $+66^\circ$, $+140^\circ$, -52° and $+92^\circ$, respectively)

- (1) 'invert sugar' is prepared by acid catalyzed hydrolysis of maltose
- (2) 'invert sugar' is an equimolar mixture of D-(+)-glucose and D-(−)-fructose
- (3) specific rotation of 'invert sugar' is -20°
- (4) on reaction with Br_2 water, 'invert sugar' forms saccharic acid as one of the products

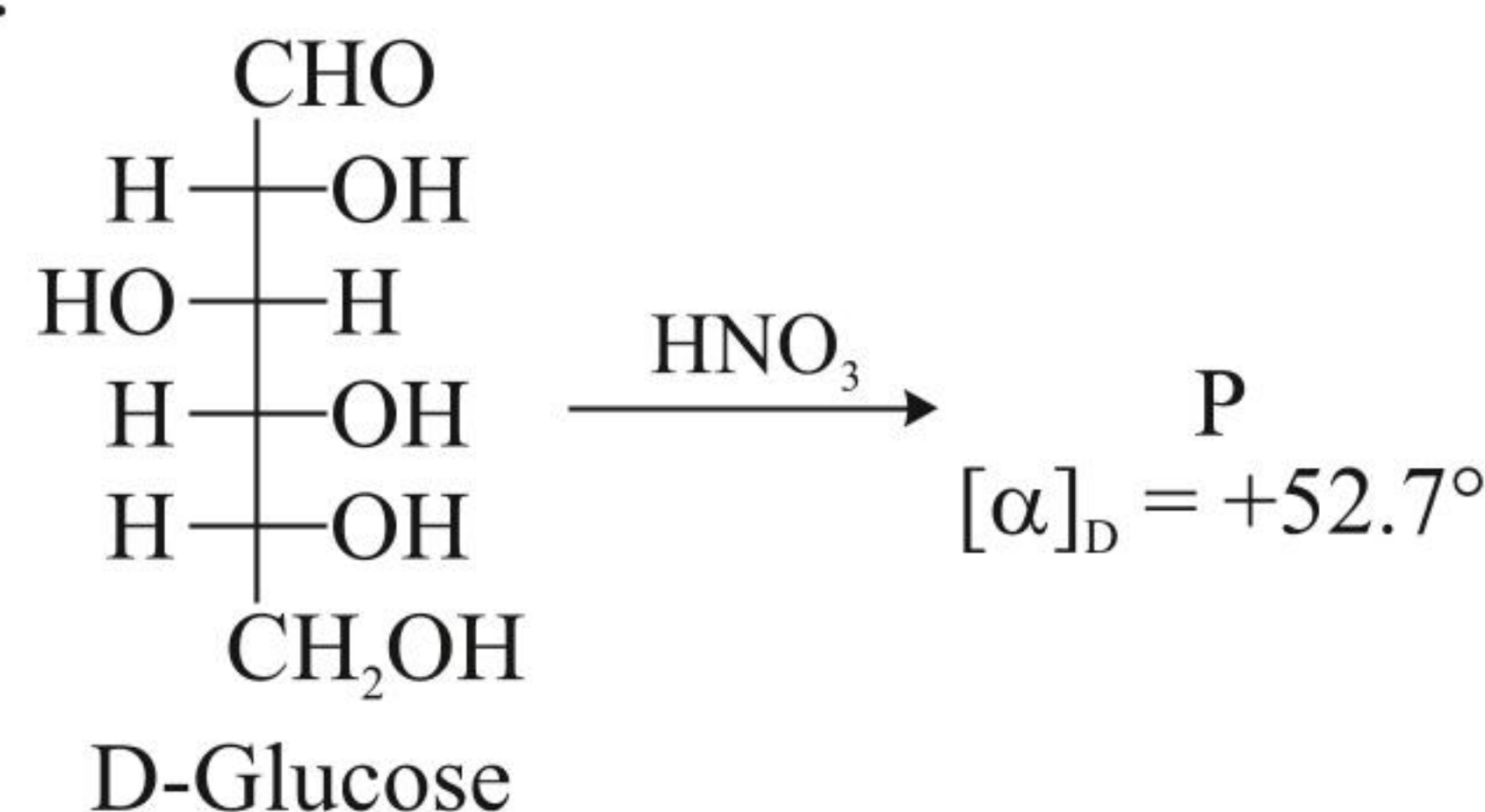
(JEE Advanced 2016)

3. Which of the following statements(s) is (are) true ?

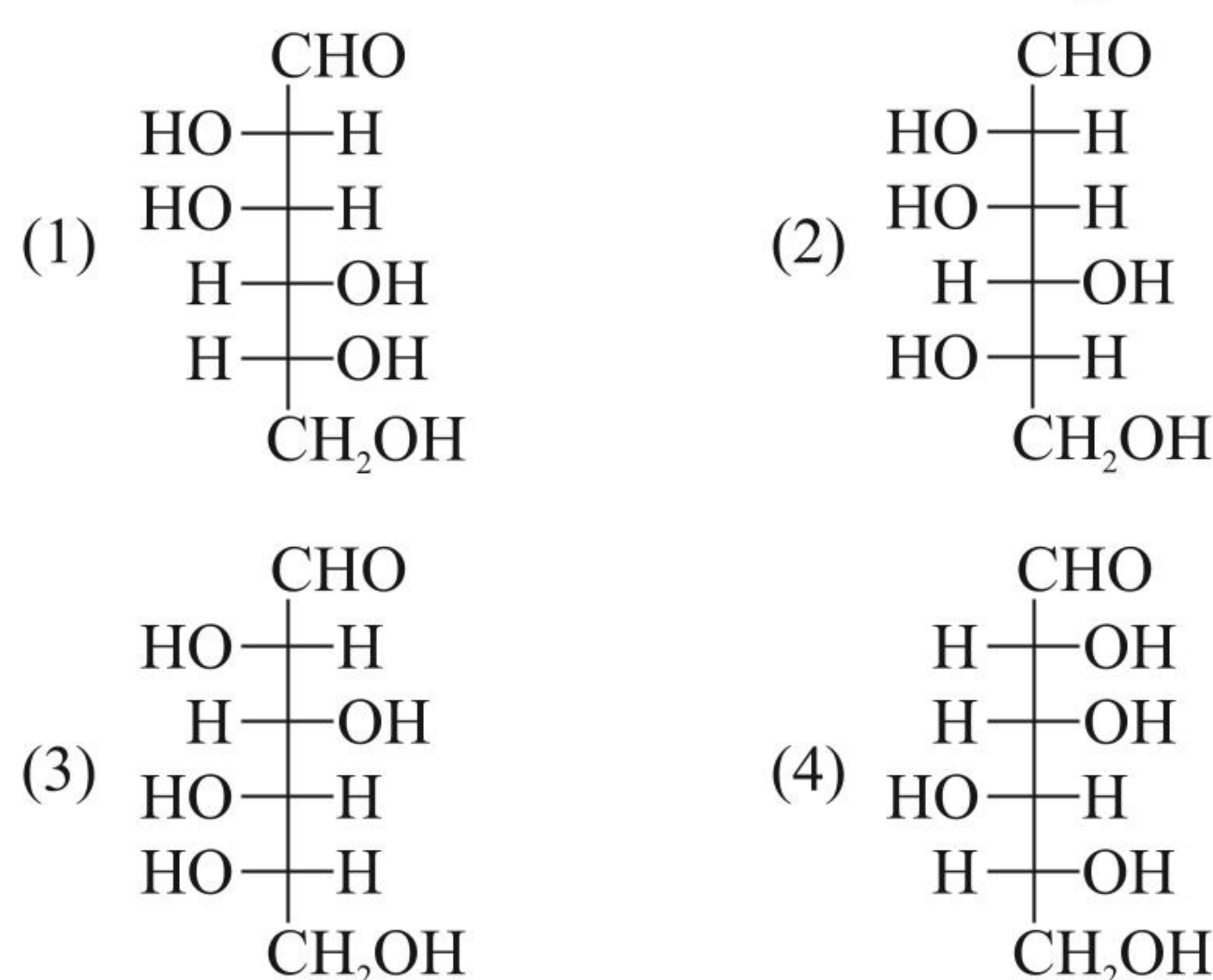
- (1) Oxidation of glucose with bromine water gives glutamic acid
- (2) The two six-membered cyclic hemiacetal forms of D-(+)-glucose are called anomers
- (3) Monosaccharides cannot be hydrolysed to give polyhydroxy aldehydes and ketones
- (4) Hydrolysis of sucrose gives dextrorotatory glucose and laevorotatory fructose

(JEE Advanced 2019)

4. Given:



The compound(s), which on reaction with HNO_3 will give the product having degree of rotation, $[\alpha]_D = -52.7^\circ$ is (are)



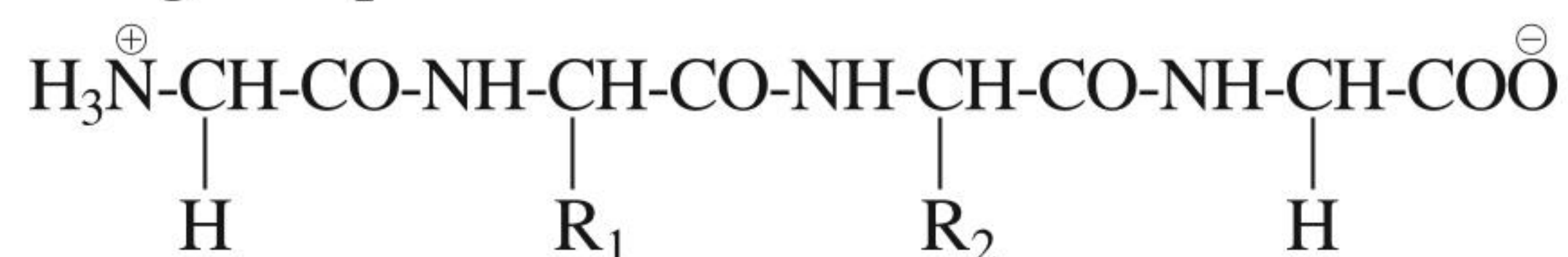
(JEE Advanced 2021)

Numerical Value Type

1. A decapeptide (Mol. Wt. 796) on complete hydrolysis gives glycine (Mol. Wt. 75), alanine and phenylalanine. Glycine contributes 47.0% to the total weight of the hydrolysed products. The number of glycine units present in the decapeptide is

(IIT-JEE 2011)

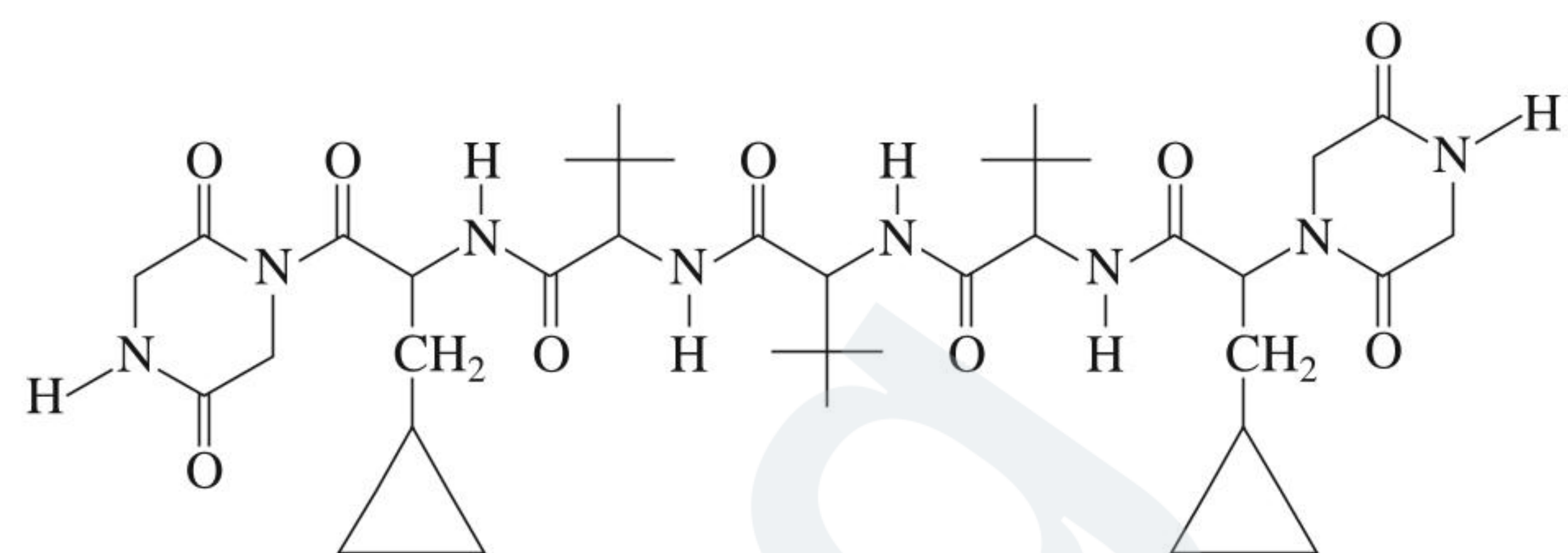
2. A tetrapeptide has-COOH group on alanine. This produces glycine (Gly), valine (Val), phenyl alanine (Phe) and alanine (Ala), on complete hydrolysis. For this tetrapeptide, the number of possible sequences (primary structures) with $-\text{NH}_2$ group attached to a chiral center is **(IIT-JEE 2012)**
3. When the following aldohexose exists in its D-configuration, the total number of stereoisomers in its pyranose form is
 $\text{OHC}-\text{CH}_2-(\text{CHOH})_3-\text{CH}_2\text{OH}$ **(IIT-JEE 2012)**
4. The substituents R_1 and R_2 for nine peptides are listed in the table given below. How many of these peptides are positively charged at $\text{pH} = 7.0$?



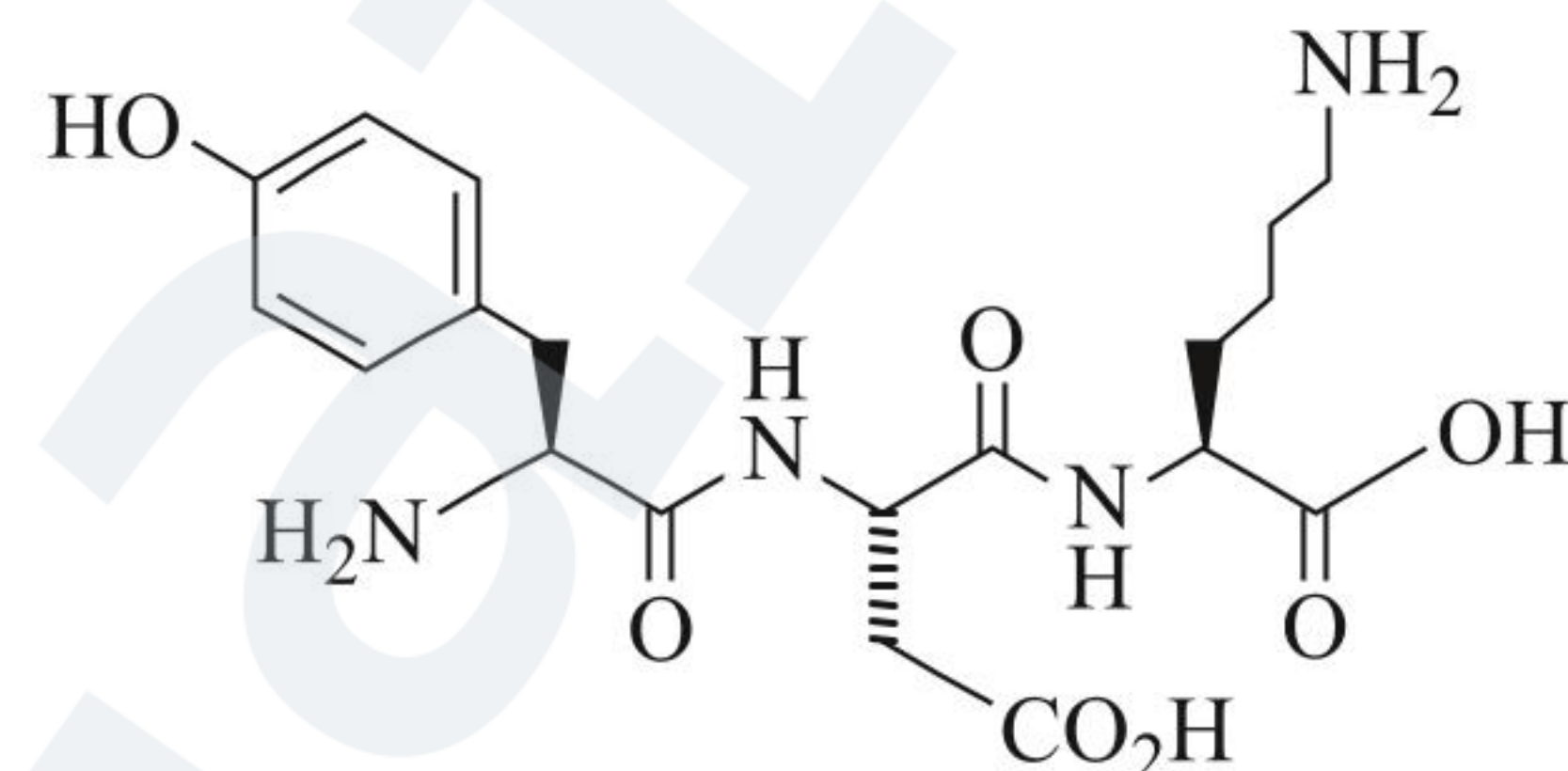
Peptide	R_1	R_2
I	H	H
II	H	CH_3
III	CH_2COOH	H
IV	CH_2CONH_2	$(\text{CH}_2)_4\text{NH}_2$
V	CH_2CONH_2	CH_2CONH_2
VI	$(\text{CH}_2)_4\text{NH}_2$	$(\text{CH}_2)_4\text{NH}_2$
VII	CH_2COOH	CH_2CONH_2
VIII	CH_2OH	$(\text{CH}_2)_4\text{NH}_2$
IX	$(\text{CH}_2)_4\text{NH}_2$	CH_3

(IIT-JEE 2012)

5. The total number of distinct naturally occurring amino acids obtained by complete acidic hydrolysis of the peptide shown below is

**(JEE Advanced 2014)**

6. The structure of a peptide is given below



If the absolute values of the net charge of the peptide at $\text{pH} = 2$, $\text{pH} = 6$ and $\text{pH} = 11$ are $|Z_1|$, Z_2 and $|Z_3|$, respectively, then what is $|Z_1| + |Z_2| + |Z_3|$?

(JEE Advanced 2020)

Answers Key

EXERCISES

Single Correct Answer Type

1. (4) 2. (3) 3. (3) 4. (2) 5. (1)
6. (1) 7. (1) 8. (1) 9. (2) 10. (2)
11. (1) 12. (1) 13. (4) 14. (1) 15. (2)
16. (3) 17. (4) 18. (2) 19. (2) 20. (3)
21. (3) 22. (4) 23. (3) 24. (4) 25. (2)
26. (2) 27. (3) 28. (2) 29. (1) 30. (4)
31. (3) 32. (1) 33. (4) 34. (4) 35. (3)
36. (4) 37. (2) 38. (4) 39. (1) 40. (2)
41. (2) 42. (4) 43. (2) 44. (4) 45. (4)
46. (4) 47. (1) 48. (1) 49. (2) 50. (2)
51. (4) 52. (4) 53. (3) 54. (1) 55. (2)
56. (3) 57. (4) 58. (3) 59. (4) 60. (2)
61. (4) 62. (1) 63. (1) 64. (4) 65. (2)
66. (1) 67. (2) 68. (2) 69. (2) 70. (3)
71. (3) 72. (1) 73. (4) 74. (3) 75. (2)
76. (3) 77. (4) 78. (1) 79. (3) 80. (2)
81. (1) 82. (4) 83. (3) 84. (4) 85. (1)
86. (2) 87. (3) 88. (3) 89. (1) 90. (4)
91. (3) 92. (1) 93. (2) 94. (4) 95. (3)
96. (4) 97. (4) 98. (3) 99. (4) 100. (4)
101. (3) 102. (4) 103. (1) 104. (4) 105. (3)
106. (2) 107. (4) 108. (2) 109. (2) 110. (3)
111. (1) 112. (2) 113. (1) 114. (2) 115. (1)
116. (3) 117. (3) 118. (3) 119. (3) 120. (2)
121. (3) 122. (1) 123. (1) 124. (4) 125. (4)
126. (1) 127. (1) 128. (4) 129. (1) 130. (3)
131. (4) 132. (3) 133. (2) 134. (2) 135. (3)
136. (2) 137. (2) 138. (3) 139. (2) 140. (3)
141. (4) 142. (4) 143. (2) 144. (1) 145. (1)
146. (4) 147. (1) 148. (4) 149. (3) 150. (3)
151. (3) 152. (1) 153. (4) 154. (3) 155. (1)

Multiple Correct Answers Type

1. (3) 2. (1, 3, 4) 3. (1, 3)
4. (1, 2, 3) 5. (1, 2, 4) 6. (1, 3, 4)
7. (1, 2, 3, 4) 8. (1, 2, 3, 4) 9. (1, 2)
10. (2, 3) 11. (1, 3, 4) 12. (3, 4)
13. (2, 3, 4) 14. (1, 2, 3) 15. (1, 2, 4)
16. (1, 2) 17. (1, 4) 18. (1, 2, 3)
19. (1, 2, 3, 4) 20. (1, 2, 4) 21. (1, 2, 3, 4)
22. (1, 2, 3, 4) 23. (1) 24. (2, 3)
25. (1, 2, 3) 26. (2, 3, 4) 27. (1, 2, 3, 4)
28. (1, 2, 3, 4) 29. (1, 3) 30. (3, 4)
31. (2, 3, 4) 32. (2, 3, 4) 33. (1, 2)
34. (1, 2, 3) 35. (3, 4) 36. (1, 2)

37. (3, 4) 38. (1, 2) 39. (2, 3)
40. (1) 41. (1, 2, 3, 4) 42. (1, 4)
43. (2, 4) 44. (1, 2, 3) 45. (1, 3)
46. (1, 4) 47. (1, 2, 3, 4) 48. (1, 2, 3)
49. (1) 50. (1, 2, 3) 51. (1, 2)
52. (1, 2, 3, 4) 53. (1, 2, 3) 54. (1, 2, 3)
55. (2, 3) 56. (2, 3, 4) 57. (2)
58. (1, 2, 3) 59. (1, 4) 60. (1, 2)
61. (1, 2, 3) 62. (1, 3, 4) 63. (1)
64. (3)

Linked Comprehension Type

1. (3) 2. (2) 3. (1) 4. (1) 5. (1)
6. (2) 7. (3) 8. (2) 9. (2,3,4) 10. (3)
11. (3) 12. (4) 13. (1,4) 14. (2,4) 15. (3)
16. (3) 17. (4) 18. (1,4) 19. (1) 20. (2)
21. (4) 22. (3) 23. (1) 24. (2) 25. (1)
26. (1,3) 27. (3) 28. (1) 29. (1)

Matching Column Type

S. No.	a	b	c	d	e	f
1.	p, q, r, s	p, q, r, s	u	q, r, s	q, r, s, u,	q, r, s, t
2.	t	p	s	q	r	—
3.	r	s	p	q	—	—
4.	q	p	s	r	—	—
5.	iv, p	i, q	ii, v, r, t	iii, s	—	—

Numerical Value Type

1. (5) 2. (2) 3. (10) 4. (3) 5. (3)
6. (3) 7. (5) 8. (2) 9. (4) 10. (4)
11. (3) 12. (8) 13. (2) 14. (8) 15. (2)
16. (4) 17. (0)

ARCHIVES

JEE Advanced

Single Correct Answer Type

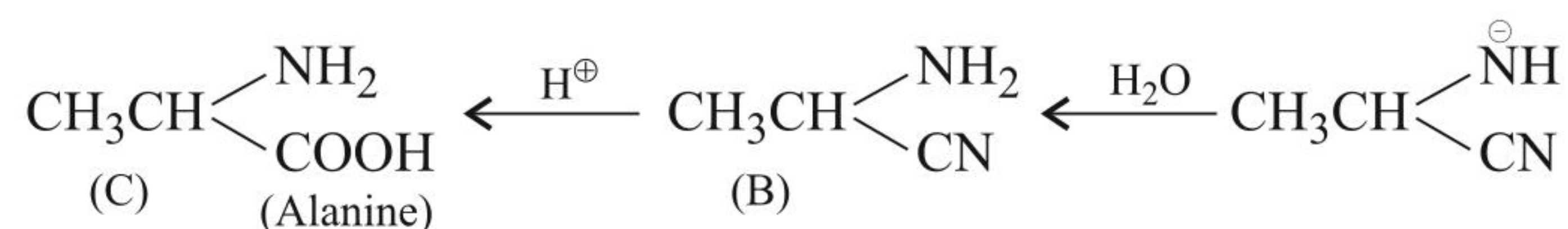
1. (4) 2. (2) 3. (1) 4. (3) 5. (4)

Multiple Correct Answers Type

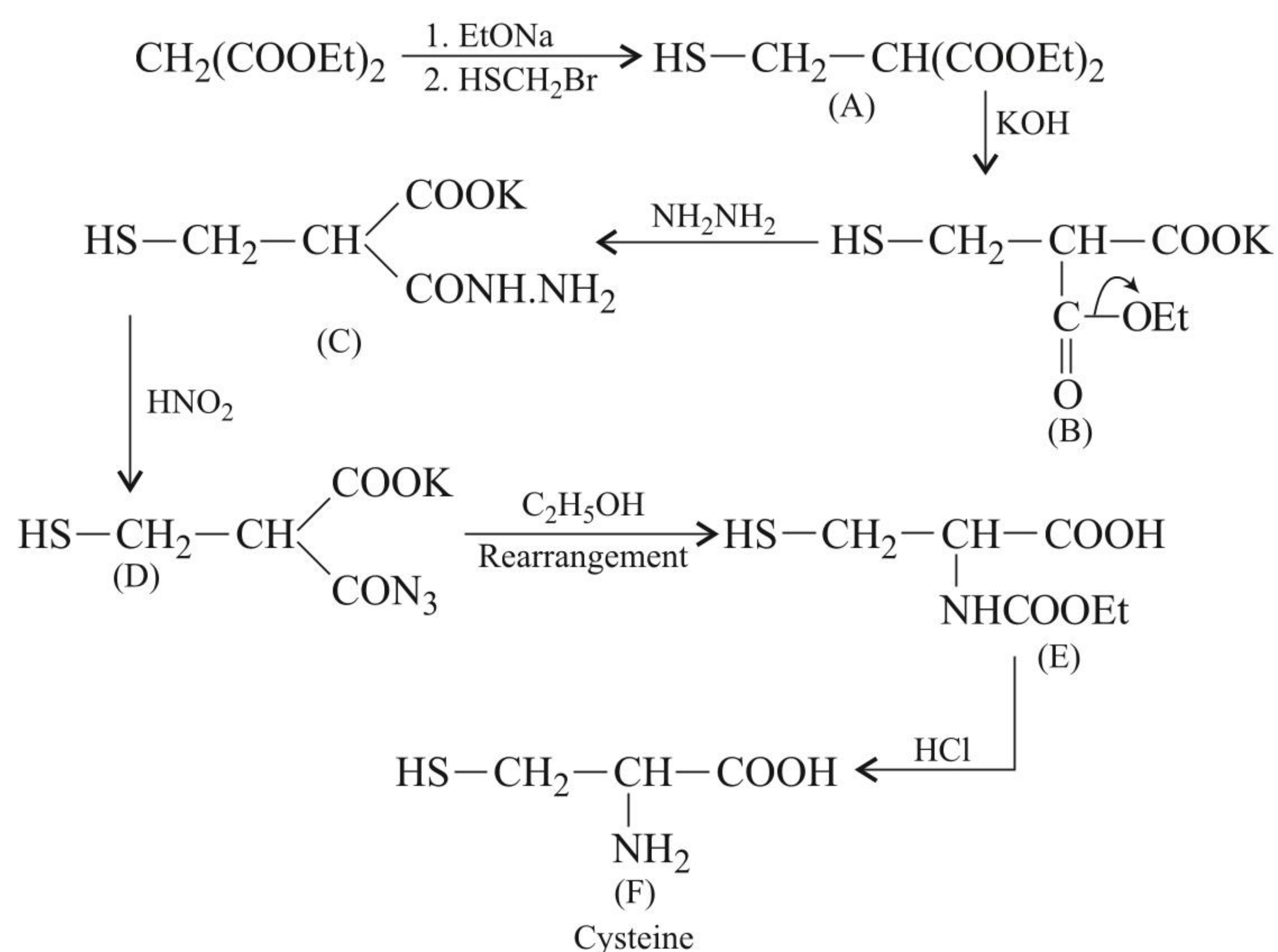
1. (2, 3) 2. (2, 3) 3. (2, 3, 4) 4. (3, 4)

Numerical Value Type

1. (6) 2. (4) 3. (8) 4. (4) 5. (1)
6. (5)

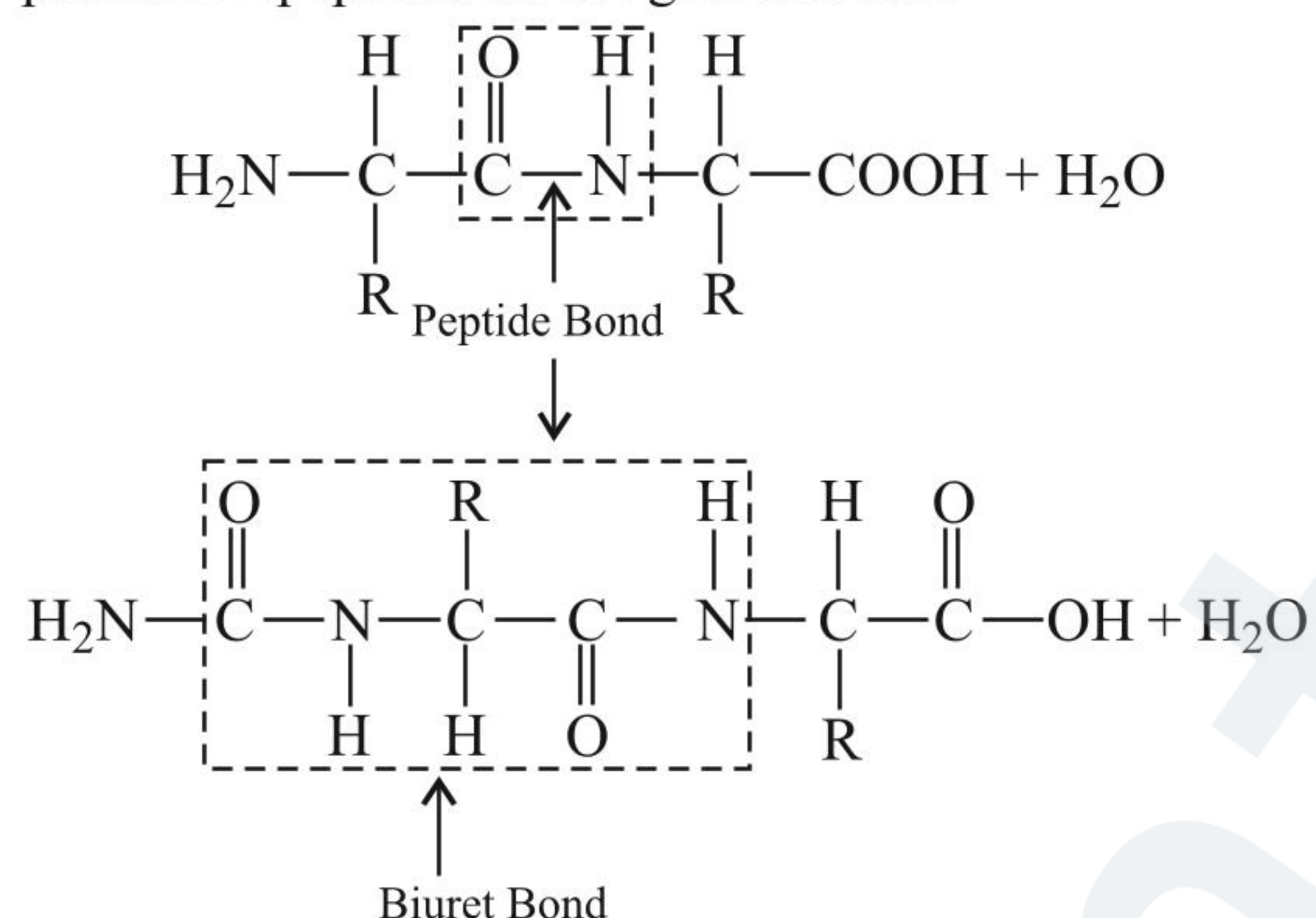


(c) It is an example of Curtius reaction.



2. Test For Proteins:

- a. **Biuret reaction:** Biuret reagent is a mixture of sodium hydroxide and copper sulphate. The blue colour of the reagent turns violet in the presence of proteins. At least two peptide linkages must be present. Dipeptides do not give this test.



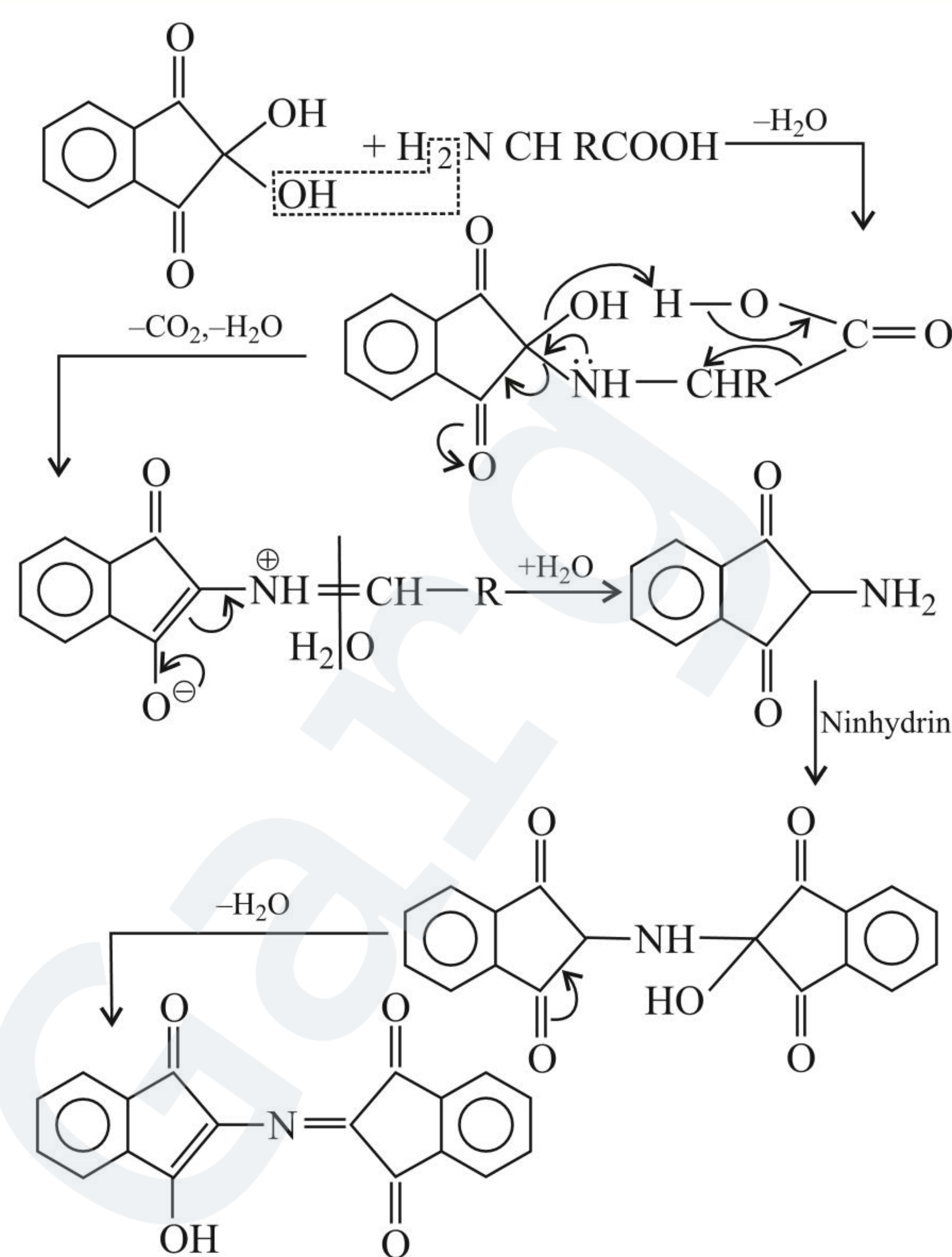
- b. **Xanthoproteic reaction:** Protein + Conc. $\text{HNO}_3 \rightarrow$ Orange in alkaline solution.
This is due to nitration of benzene ring in phenylalanine, tyrosine, and tryptophan.

- c. **Million's test:** $(\text{Hg}(\text{NO}_3)_2 + \text{HNO}_3 + \text{Traces of } \text{HNO}_2)$



This is a characteristic of phenol, so it is given by proteins containing tyrosine (only phenolic amino acid that occurs in proteins)

- d. **Ninhydrin test:** (Indane-1,2,3-trione hydrate)



Ninhydrin is used as a spraying reagent in the identification and quantitative estimation of amino acids. TNBS (sodium 2,4,6-trinitro benzene-1-sulphonate) is also used. Diazotised sulphanilic acid couples with tyrosine and histidine in alkaline solution to give red colour.

Exercise 9.3

- a. **Gene:** A gene is a sequence of base triplets in a strand of DNA helix that functions to code a polypeptide chain. The polypeptide chain ultimately becomes the part of the protein synthesised. Every protein in a cell has the corresponding gene.

b. **Genetic code:** The relation between the amino acids and the nucleotide triplet is called genetic code.

c. **Transcription:** The way the code on DNA is copied to give the complementary code on RNA is called transcription.

d. **Translation:** The way the four-base code in nucleic acids is turned into a 20 unit code needed to specify the amino acid sequence in proteins during synthesis is called translation.

e. **Codons:** The nucleotide bases in RNA function in groups of three (triplets) in coding amino acids. These base triplets are called codons.
- i. Nucleotides are the building blocks of high molecular weight polymers (poly-nucleotides) called nucleic acids.

ii. Some of them act as energy carriers.

iii. In the sequence of three, they code for one amino acid in nucleic acids. Thus, some of them are carriers of hereditary information, i.e., genetic code.

iv. Some of them are co-enzymes.
- DNA consists of two strands of polynucleotides coiled around each other in the form of a double helix. The nucleotides making up each strand of DNA are connected by phosphate ester bonds. This forms the backbone of each DNA strand, from which the bases extend. The bases of one strand of DNA are paired with the bases on the other strand by means of hydrogen bonding. This hydrogen bonding is very specific as the structure of bases permits only one mode of pairing. Adenine pairs only thymine *via* two hydrogen

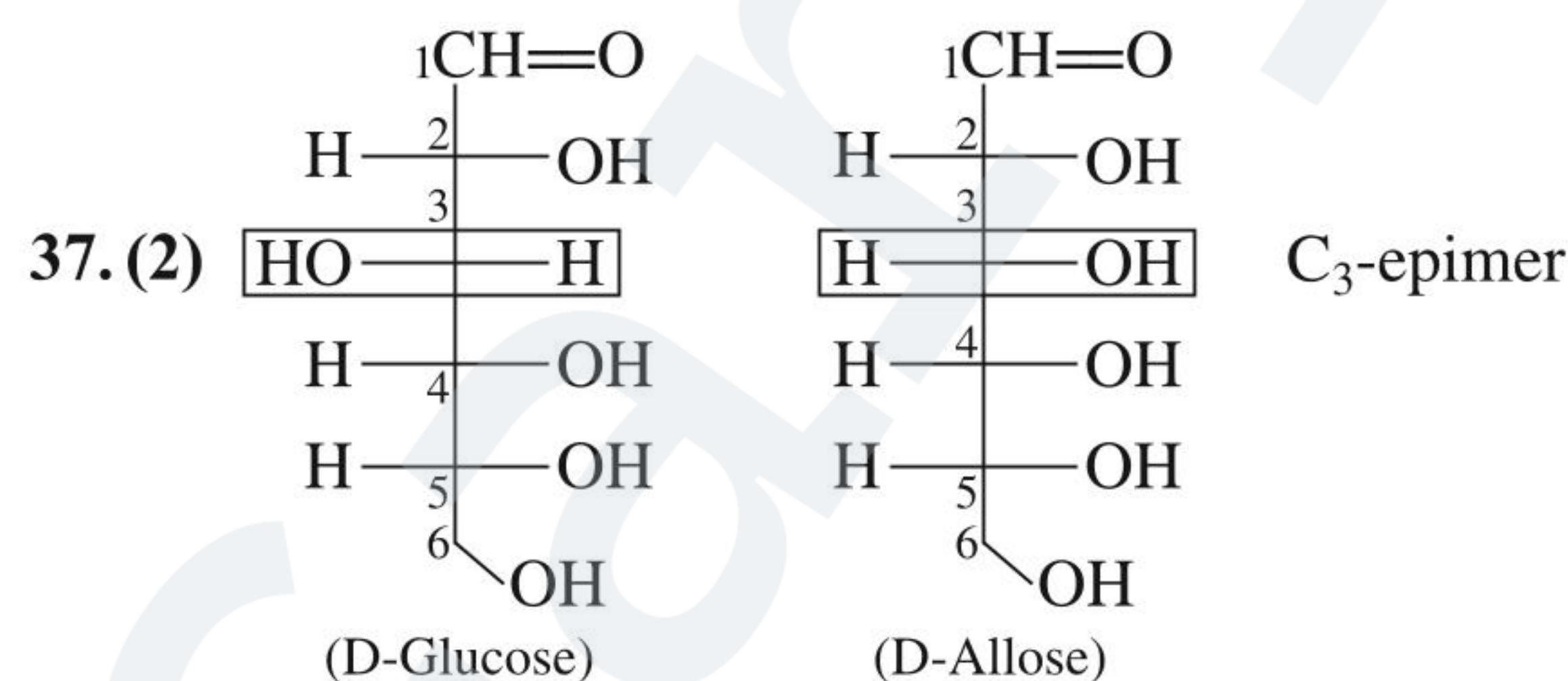
bonds and guanine pairs with cytosine through three hydrogen bonds. The two strands of DNA are said to be complementary to each other in the sense that the sequence of bases in one strand automatically determines that of the other. These strands are not identical.

4. i. They form structural component of cells. For example, cellulose is present in the cell walls of all the plant cells.
ii. They function as biofuels to provide energy for the functioning of living system and doing work.
5. Globular protein may have the following types of bonding: hydrogen bonding, disulphide bridges, ionic or salt bridges, and hydrophobic interactions.
6. Sequence of bases on mRNA molecule:
DNA strand TAT CTA CCT GGA
m-RNA AUA GAU GGA CCU
7. Maltose or lactose (reducing)
Sucrose (non-reducing)
8. Keratin (fibrous)
Haemoglobin (globular)
9. Defective haemoglobin
10. Cheese
11. Insulin
12. Nucleoside is obtained when a nitrogenous base (purine or pyrimidine) is attached to C₁ of a sugar (ribose or deoxyribose) by β -linkage.
13. Nucleotide is obtained when C₅ - OH of the sugar (ribose or deoxyribose) of a nucleoside is esterified with phosphoric acid.
14. Adenine and guanine (purine base) in DNA and RNA. Cytosine, thymine, and uracil (pyrimidine base)
15. The phenomenon involving the change in the specific rotation of sugar with time, till it attains a constant value is called mutarotation.
16. The amino acids having one amino and one carboxylic group are called neutral amino acids. Examples: Glycine and alanine.
17. Amino acids having two carboxylic groups and one amino group such as aspartic acid and glutamic acid.
18. Amino acids containing two amino groups and one carboxylic group. Example: Lysin.
19. Amylase and maltase
20. The deficiency of protein in our body causes a disease called **Kwashiorkar**.
21. Glucose < Sucrose < Fructose
22. Streptokinase.
23. mRNA, tRNA, and rRNA
24. The compounds that generate energy in living cells on metabolism are called biofuels. Examples: Carbohydrates and fats.
25. The amino acids such as glycine and alanine are the monomers that constitute proteins.
26. It is the property of an enzyme by which it will discriminate or select only a limited number of compounds for attack.
27. The low or high pH values can cause denaturation of the protein and hence make enzyme's protein inactive.
28. Nucleic acids have two important functions:
 - i. Replication: Due to its unique property of self replication (process by which a single DNA molecule produces two identical species of itself), it is responsible for maintaining the heredity traits from one generation to another.
 - ii. Protein synthesis: RNA helps in the biosynthesis of proteins and is, in one way, responsible for the process of learning and memory storage. Furthermore, it sends information and instructions to the cell for the manufacture of specific proteins.

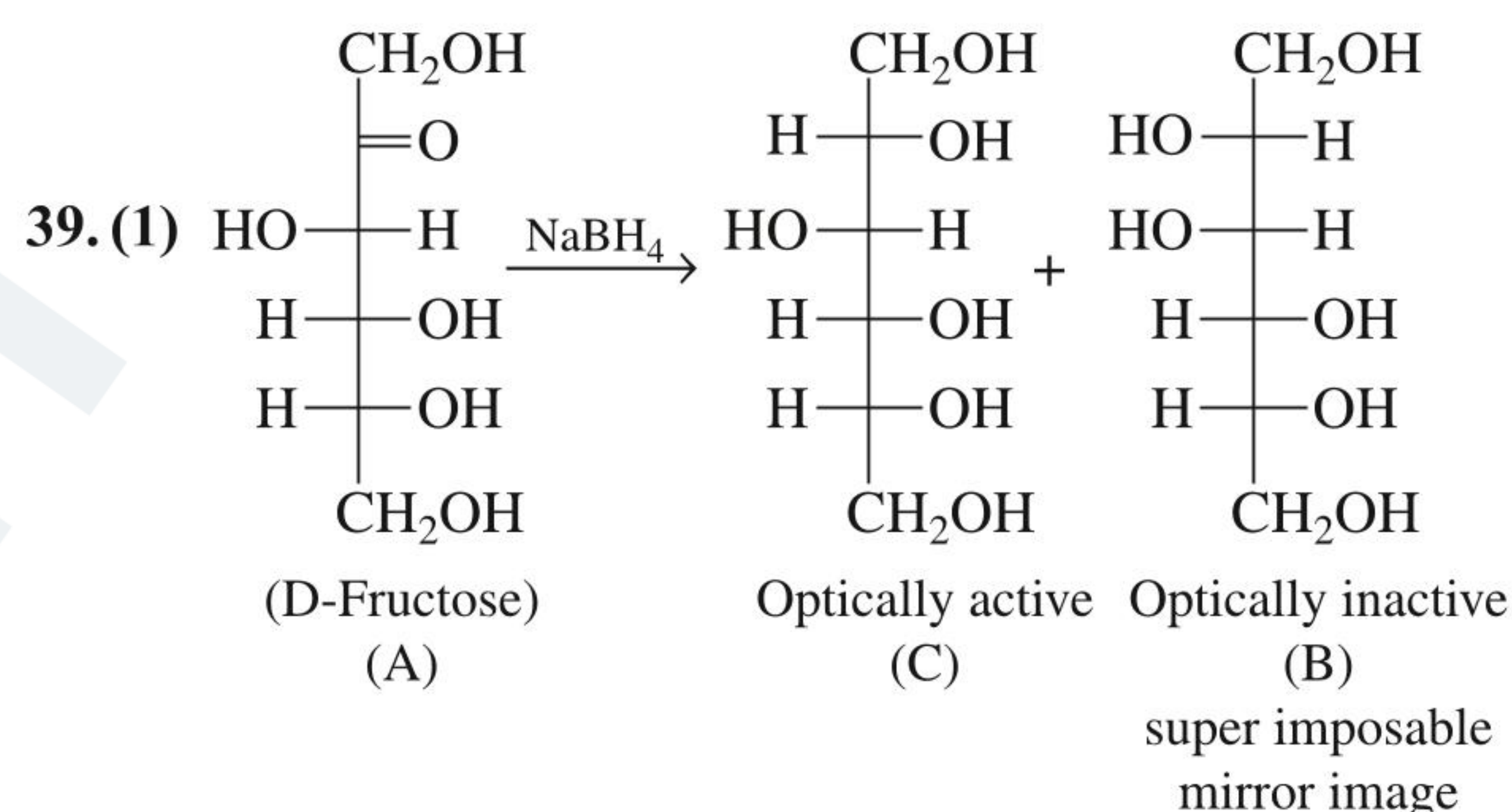
Exercises

Single Correct Answer Type

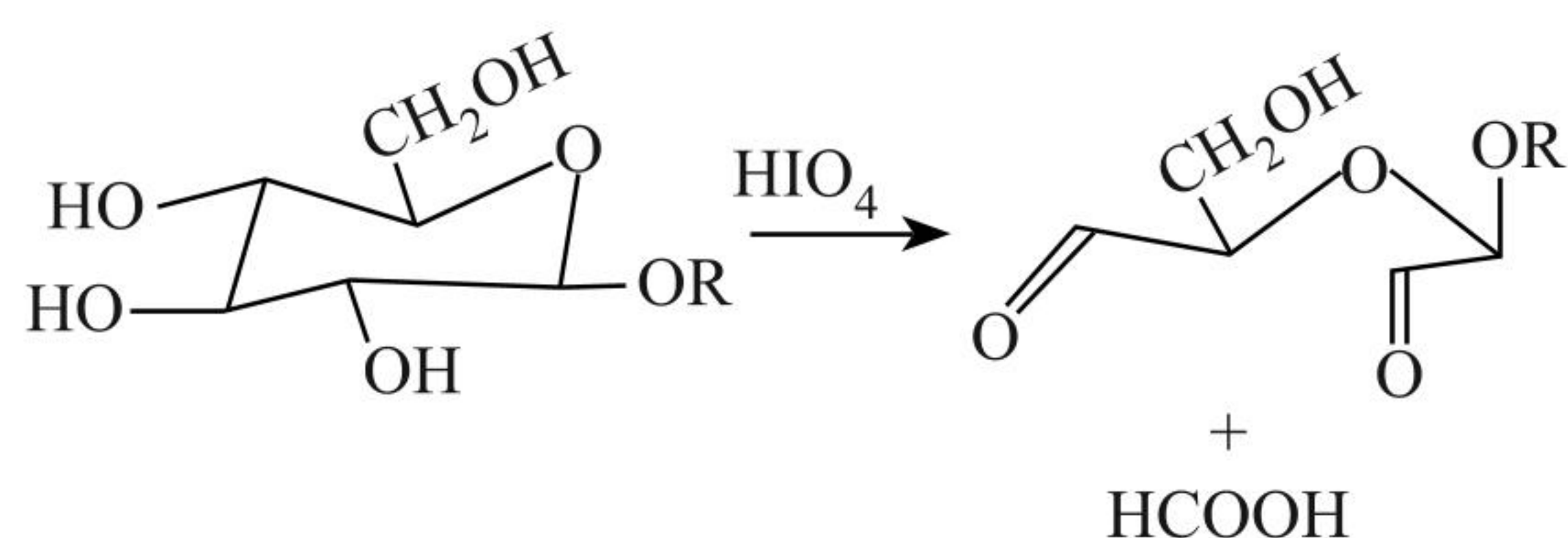
- | | | | | |
|---------|---------|---------|---------|---------|
| 1. (4) | 2. (3) | 3. (3) | 4. (2) | 5. (1) |
| 6. (1) | 7. (1) | 8. (1) | 9. (2) | 10. (2) |
| 11. (1) | 12. (1) | 13. (4) | 14. (1) | 15. (2) |
| 16. (3) | 17. (4) | 18. (2) | 19. (2) | 20. (3) |
| 21. (3) | 22. (4) | 23. (3) | 24. (4) | 25. (2) |
| 26. (2) | 27. (3) | 28. (2) | 29. (1) | 30. (4) |
| 31. (3) | 32. (1) | 33. (4) | 34. (4) | 35. (3) |
| 36. (4) | | | | |



38. (4) When only second carbon have opposite stereo-chemistry and remaining compound is exactly same then two compound is known as C₂-epimer, i.e., D-mannose.



40. (2) Non-reducing sugars do not undergo mutarotation.
41. (2) α and β forms
42. (4) D-glucose $\xrightarrow[\text{H}_2\text{O}]{\text{Br}_2}$ D-gluconic acid
D-Fructose $\xrightarrow[\text{H}_2\text{O}]{\text{Br}_2}$ No reaction.
43. (2) $2^5/2^4 = 2$
44. (4) Sucrose does not have any free anomeric carbon that is why it is non-reducing in nature.
45. (4) Polysaccharides are not reducing sugar e.g., starch, cellulose, glycogen etc. Hence fructose is reducing.
46. (4) Glucose is in dynamic equilibrium with fructose form in aqueous medium so both can not distinguish by given tests.
47. (1)
48. (1)
49. (2)
50. (2)
51. (4)
52. (4)
53. (3)
54. (1)
55. (2)
56. (3) Only 'C' contains plane of symmetry, hence optically inactive (monosaccharide) may be 3-keto poly hydroxy compound
57. (4)
58. (3)
59. (4)
60. (2)
61. (4) Gluconic acid is monocarboxylic acid whereas HNO₃ on oxidation gives dicarboxylic saccharic acid.
62. (1)
63. (1) HCOOH (unique behaviour in its own category) reduces Tollen's reagent. It confirms pyranoside form in glycoside.



64. (4) 65. (2) 66. (1) 67. (2)
 68. (2) 69. (2) 70. (3) 71. (3) 72. (1)
 73. (4)

74. (3) Sugar having hemiacetal linkage will show mutarotation.

75. (2) 76. (3) 77. (4) 78. (1)
 79. (3) 80. (2)

81. (1) $150.7(X) + 52.8(1 - X) = +80.2$

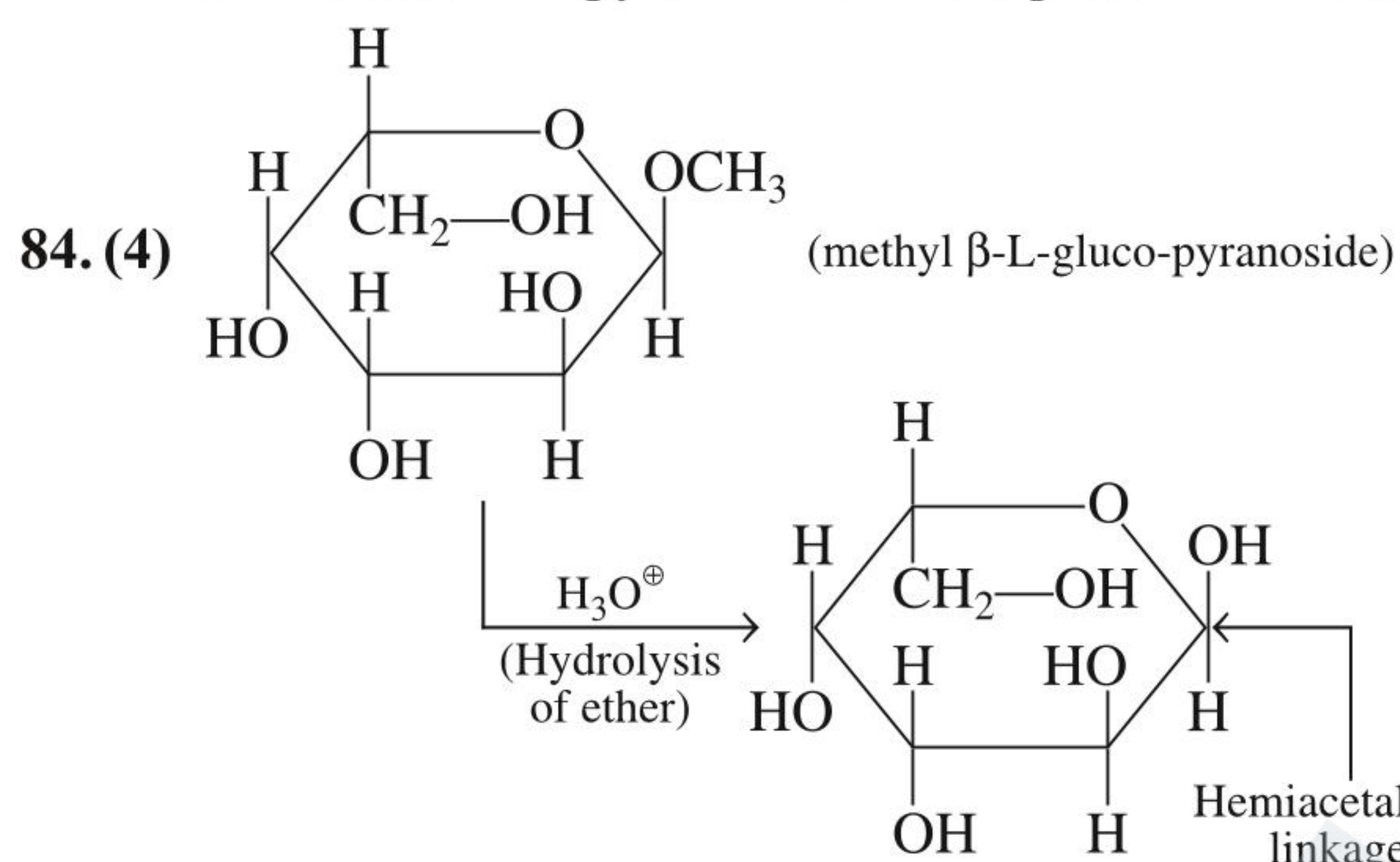
$$150.7X + 52.8 - 52.8X = +80.2$$

$$97.9X = 27.4$$

$$X = 0.279 = 0.28$$

82. (4) Compound having free anomeric carbon is reducing in nature. Therefore (4) is non-reducing.

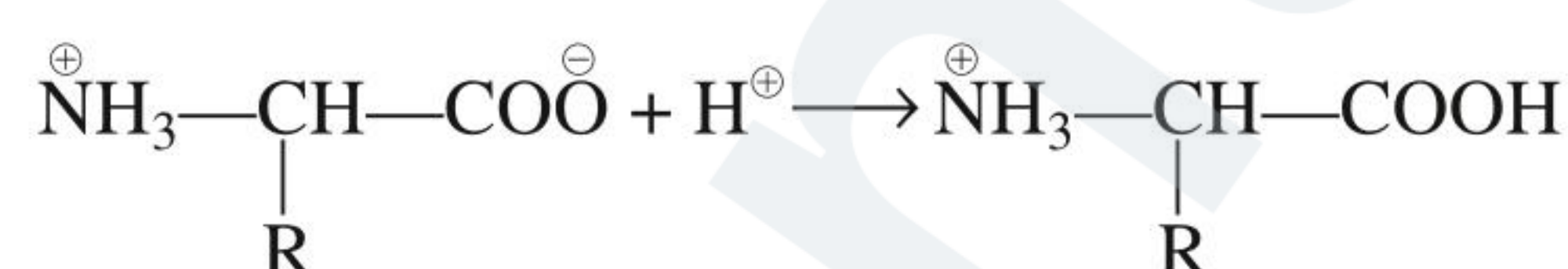
83. (3) Monomer of maltose is α -D-glucopyranose. It is disaccharide, so 2 aldose in 2 pyranose form are present in maltose.



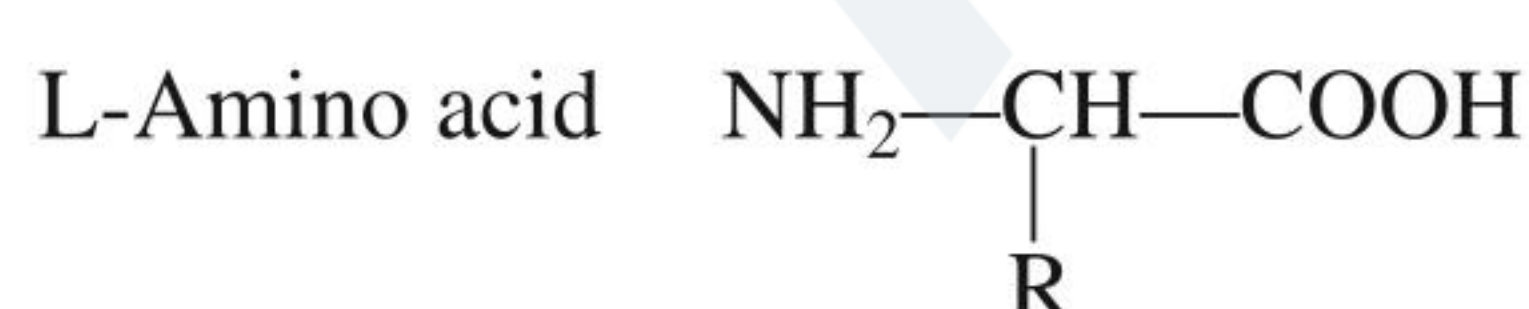
85. (1) 86. (2)
 87. (3) 88. (3) 89. (1) 90. (4) 91. (3)
 92. (1) 93. (2) 94. (4) 95. (3) 96. (4)
 97. (4) 98. (3) 99. (4) 100. (4) 101. (3)
 102. (4) 103. (1) 104. (4) 105. (3) 106. (2)
 107. (4) 108. (2) 109. (2) 110. (3) 111. (1)

112. (2) In acidic medium $\frac{4.3 + 2.2}{2} = 3.25$

113. (1) In acidic medium Zwitter ion convert into

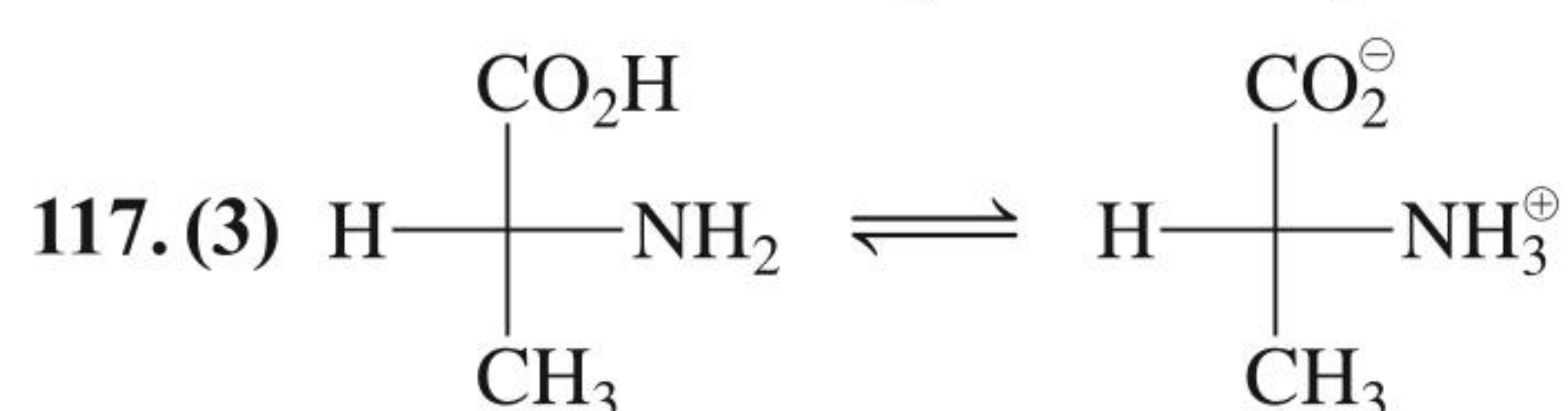


114. (2) Amino acids which combine into peptide chains to form the building blocks of a rest array of proteins are all L-stereoisomers (left handed)



115. (1) Due to resonance bond length of C—N bond gets shorter.

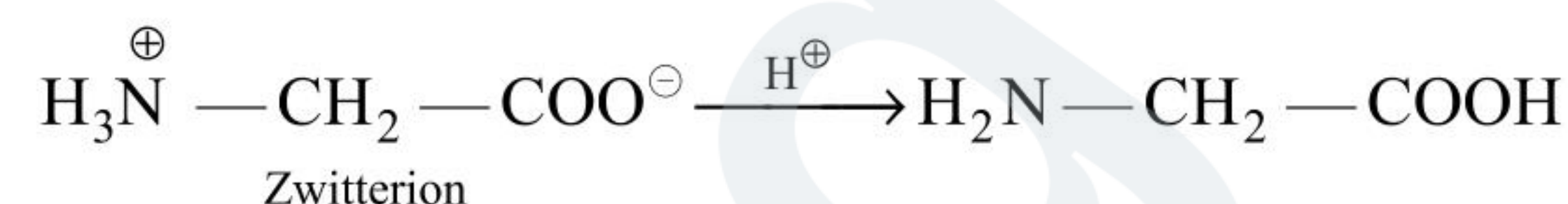
116. (3) Zwitter ion is also known as dipolar ion. Ionic compound in which ions are together directly is not called as zwitter ion.



118. (3) 119. (3) 120. (2) 121. (3) 122. (1)
 123. (1) 124. (4) 125. (4) 126. (1) 127. (1)
 128. (4) 129. (1) 130. (3) 131. (4) 132. (3)
 133. (2) 134. (2) 135. (3) 136. (2) 137. (2)
 138. (3) 139. (2) 140. (3) 141. (4)

142. (4) Haemoglobin and cytochromes are both conjugated proteins containing Fe (heme) as the prosthetic group.

143. (2) At pH = 4 (acidic range), glycine reacts with H^+ ion



144. (1) 145. (1) 146. (4) 147. (1) 148. (4)
 149. (3) 150. (3) 151. (3) 152. (1) 153. (4)
 154. (3) 155. (1)

Multiple Correct Answers Type

1. (3) 2. (1, 3, 4) 3. (1, 3)
 4. (1, 2, 3) 5. (1, 2, 4) 6. (1, 3, 4)
 7. (1, 2, 3, 4) 8. (1, 2, 3, 4) 9. (1, 2)
 10. (2, 3) 11. (1, 3, 4) 12. (3, 4)
 13. (2, 3, 4)
 14. (1, 2, 3)

First three carbon's stereochemistry or structure does not matter to form same osazone because they will react with phenyl hydrazine.

15. (1, 2, 4)

Compounds (1), (2) and (4) have atleast one —OH group attached to the anomeric carbon so they are reducing in nature or compound having hemiacetal linkage are reducing in nature.

16. (1, 2)

Compound having haemiacetal linkage on anomeric carbon are reducing in nature and will show mutarotation.

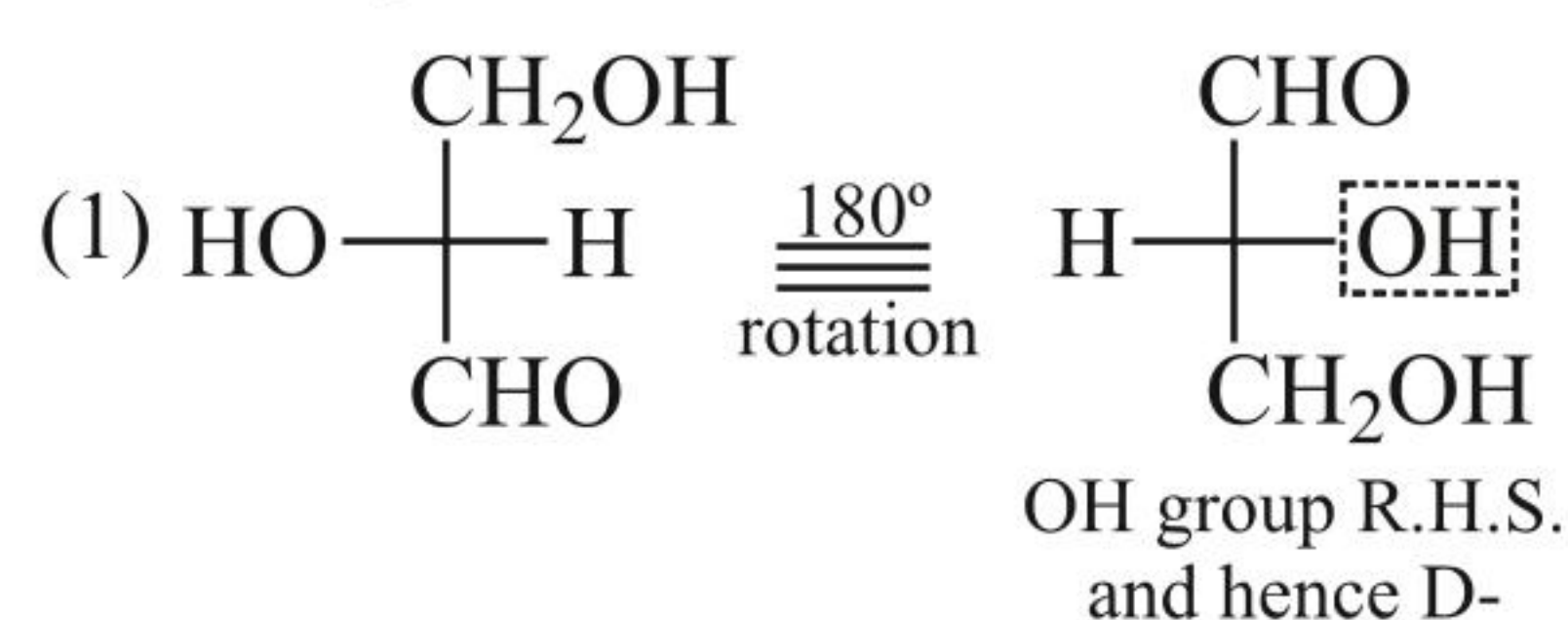
17. (1, 4)

18. (1, 2, 3) See Illustration 9.11.

19. (1, 2, 3, 4) All Statements are self-explanatory.

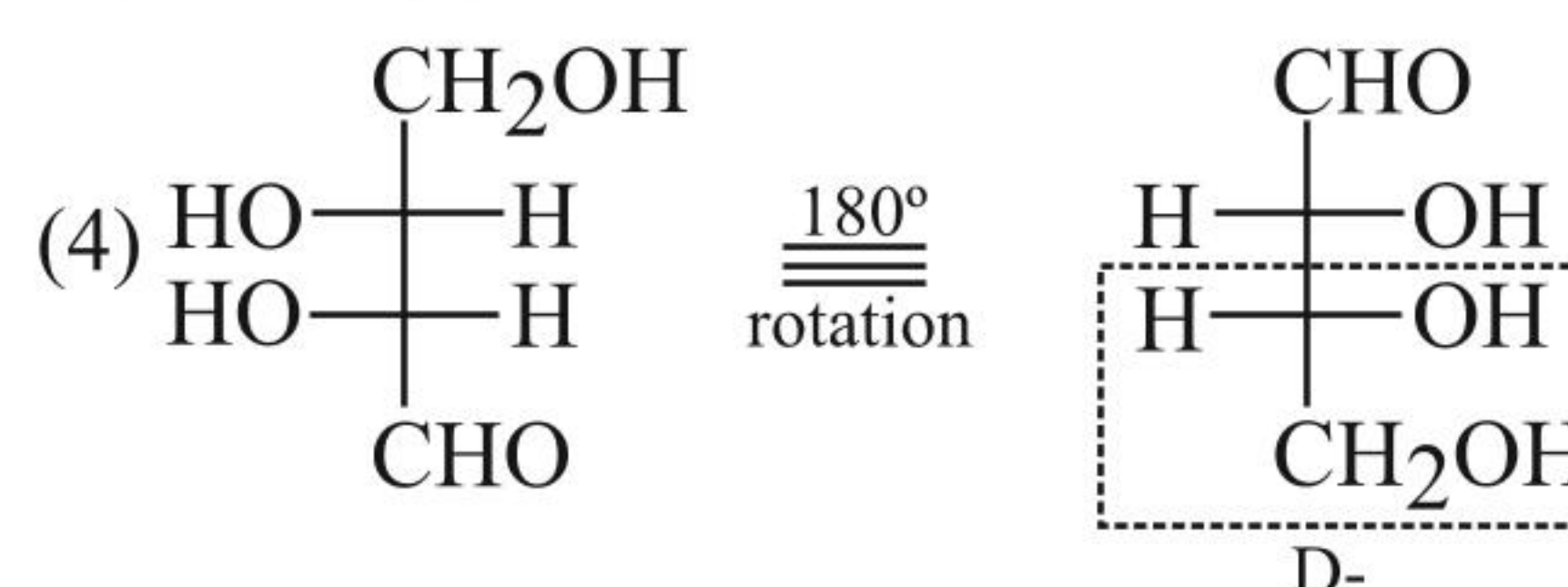
20. (1, 2, 4)

Write the structure in Fischer projection, with the functional group on the top and then find D and L.



(2) Determine R and S configurations, where R is D and S is L. The order of priorities is: OH > CHO > CH₂OH > H. So, (2) is R or D.

(3) Here, (3) is S or L.



21. (1, 2, 3, 4) 22. (1, 2, 3, 4) 23. (1)
 24. (2, 3)
 25. (1, 2, 3)

See Illustration 9.2. They are not anomers, since one glucose is in pyranose form while the other is in furanose form.

26. (2, 3, 4)

See Chapter 9, Linked Comprehension Type, Q. Nos. 19–22.

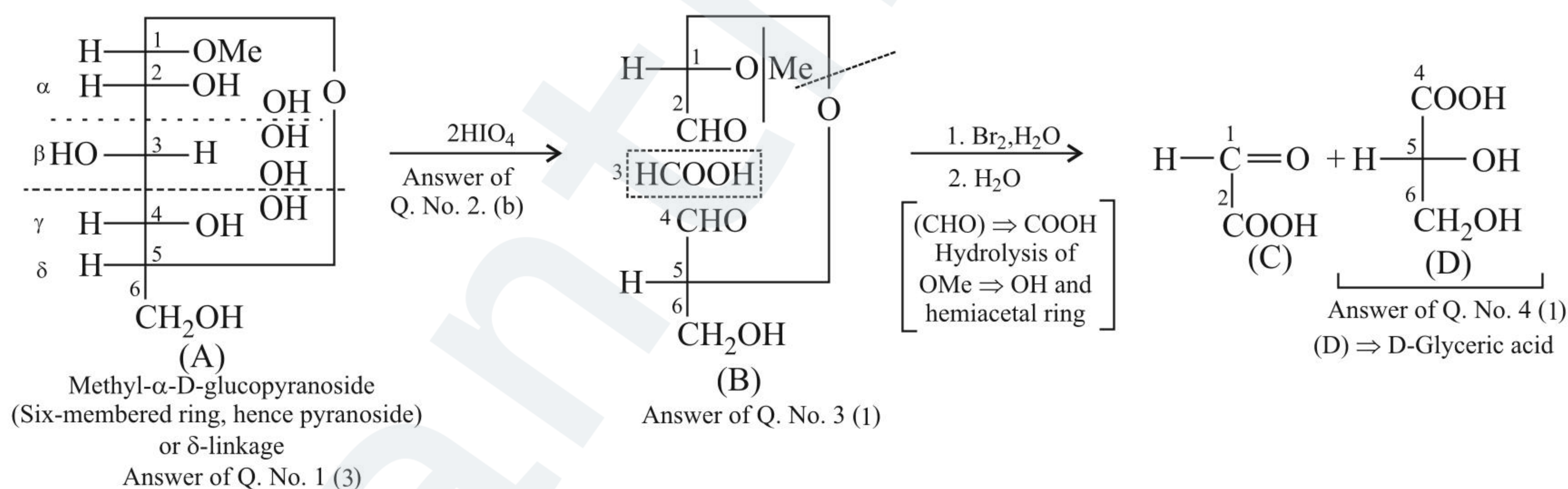
27. (1, 2, 3, 4) All of them have hemiacetalic linkage.
 28. (1, 2, 3, 4) All statements are self-explanatory.
 29. (1, 3)
 (1) False, sugars containing hemiacetal show mutarotation.
 (2) True, ketoses exist in hemiketals and possess anomers.
 (3) False; the anomeric (OH) is etherified and the equilibrium with the free carbonyl is destroyed.
 (4) True, the statement is self-explanatory.
 30. (3, 4) See Illustration 9.5.
 31. (2, 3, 4) 32. (2, 3, 4) 33. (1, 2)
 34. (1, 2, 3) 35. (3, 4) 36. (1, 2)
 37. (3, 4) 38. (1, 2) 39. (2, 3)
 40. (1) 41. (1, 2, 3, 4)
 42. (1, 4)
 In sucrose there are OH groups, so it forms octa methylated and acetylated products.
 43. (2, 4)
 Amylase hydrolyses α -linkage. (4) It exhibits mutarotation, since in β -D-glucose C-1 (OH) group is hemiacetalic.
 44. (1, 2, 3)
 Since C-1 OH group in β -D-glucose is hemiacetalic, so with MeOH/HCl, this OH group is methylated to form acetal. Thus with β -D-glucose, the word glucopyranoside is named.
 45. (1, 3)

46. (1, 4)
 47. (1, 2, 3, 4) All statements are self-explanatory.
 48. (1, 2, 3) 49. (1) 50. (1, 2, 3)
 51. (1, 2) 52. (1, 2, 3, 4) 53. (1, 2, 3)
 54. (1, 2, 3) 55. (2, 3)
 56. (2, 3, 4) All statements are self-explanatory.
 57. (2) Three base pairs code for one amino acid and two more triplets are required for 'start' and 'stop' signals, or $(3 \times 129) + (3 \times 2) = 393$ base pairs.
 58. (1, 2, 3) Statements are self-explanatory.
 59. (1, 4) 60. (1, 2)
 61. (1, 2, 3)
 (A) (with $pI = 1.1$) is in a very acidic range; has more anionic groups at $pH = 7$; and will migrate to the positive electrode (cathode). (B) ($pI = 6.7$) is present mostly with net zero charge and moves very little or will not migrate. (C) ($pH = 11.0$), the very basic protein, exists mainly in the cationic form and migrates to the negative electrode (anode). At pI , amino acids have least solubilities, so (B) ($pH = 6.7$), [pH very close to pH of the mixture ($pH = 7$)], is least soluble and would precipitate out, while (A) and (C) would remain in the solution.
 62. (1, 3, 4)
 63. (1)
 64. (3)

Linked Comprehension Type

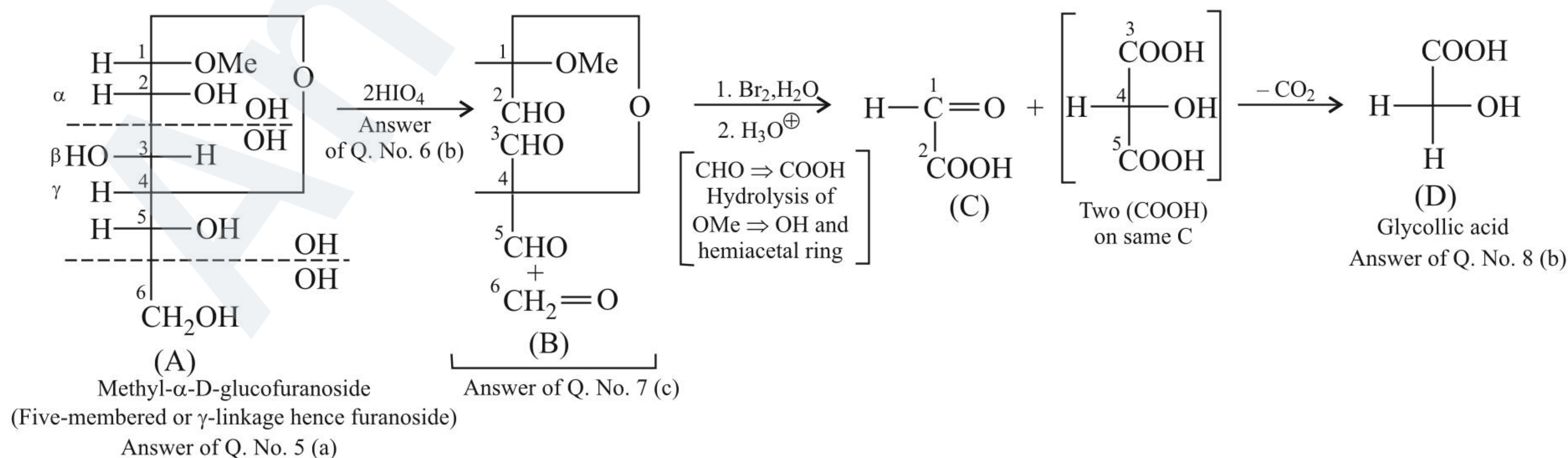
Paragraph 1

1. (3) 2. (2) 3. (1) 4. (1)



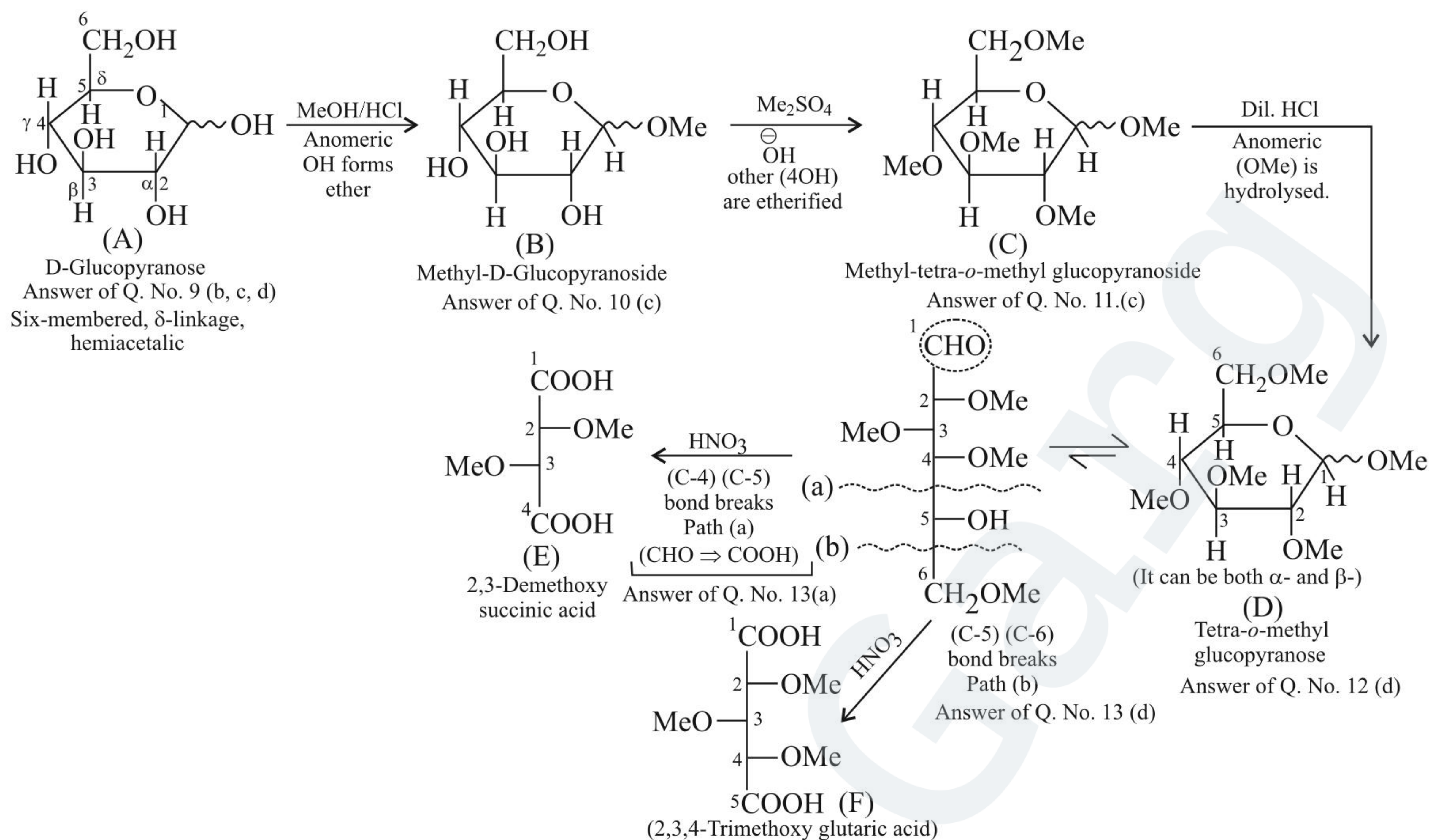
Paragraph 2

5. (1) 6. (2) 7. (3) 8. (2)



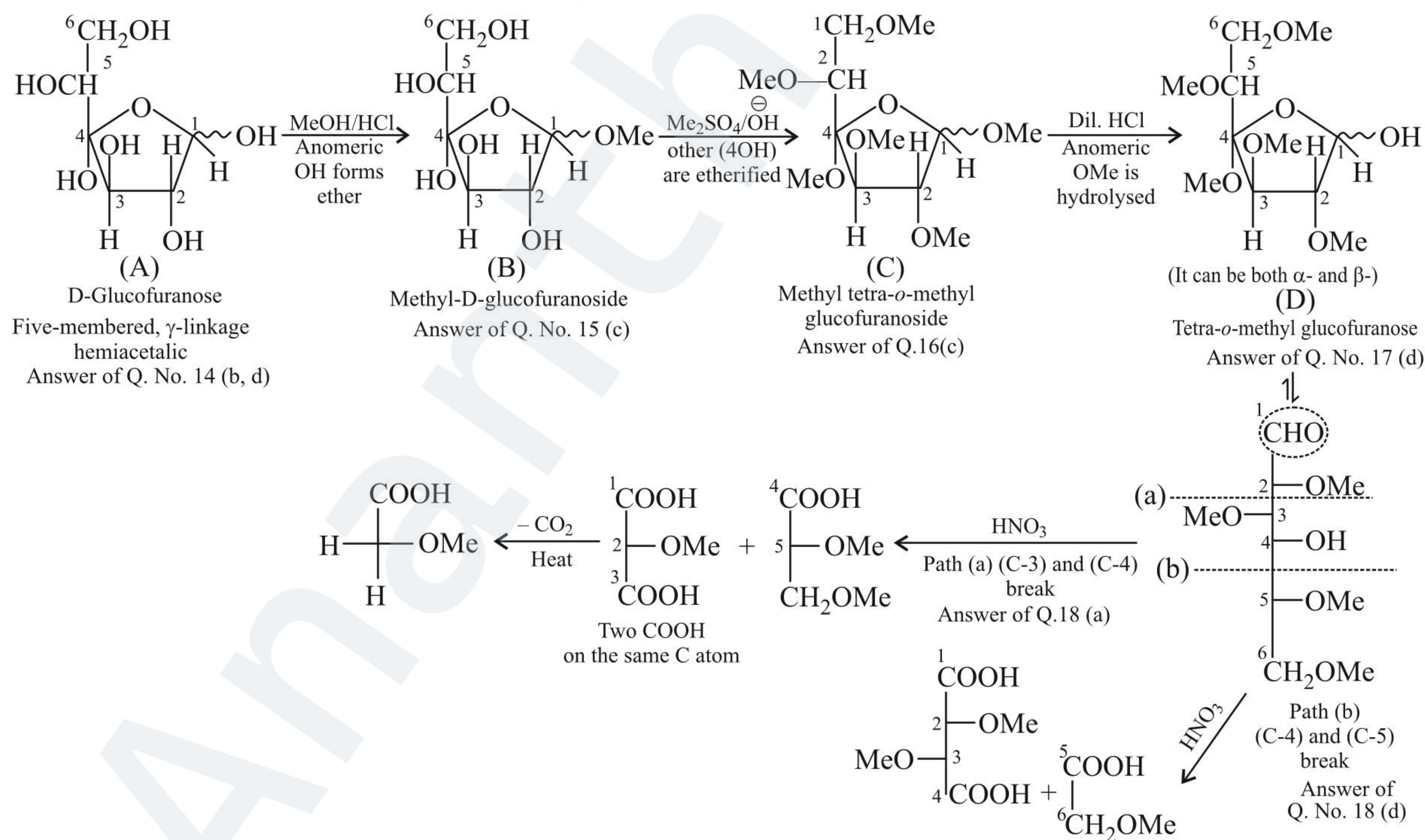
Paragraph 3

9. (2, 3, 4) 10. (3) 11. (3) 12. (4) 13. (1, 4)



Paragraph 4

14. (2, 4) 15. (3) 16. (3) 17. (4) 18. (1, 4)



Paragraph 5

19. (1) 20. (2) 21. (4)

19. (1) DNP method or Leucine aminopeptidase enzyme releases N-terminal amino acid.

Tetrapeptide $\longrightarrow$ Alanine + Tripeptide

(I) (N-terminal)

Ala $\longrightarrow$ Tripeptide
(N-terminal)

(2) Hydrazinolysis or carboxypeptidase enzyme releases C-terminal amino acid.

Tripeptide $\longrightarrow$ Dipeptide + Glycine

(II) (C-terminal)

Ala $\longrightarrow$ Dipeptide $\longrightarrow$ Gly
(N-terminal) (C-terminal)

(3) Dipeptide (III) now contains only two amino acids, valine and Leucine. Edman method releases N-terminal amino acid.

Dipeptide $\longrightarrow$ Valine $\longrightarrow$ Leucine
(III) (N-terminal) (C-terminal)

Answer of Q. No. 23. (a)

Tripeptide $\longrightarrow$ Dipeptide + Gly

(III) (Val $\rightarrow$ Leu) (C-terminal)

$\longrightarrow$ Val $\rightarrow$ Leu $\rightarrow$ Gly

Answer of Q. No. 24. (b)

Tetrapeptide $\longrightarrow$ Tripeptide + Alanine
(I) (Val $\rightarrow$ Leu $\rightarrow$ Gly) (N-terminal)

$\longrightarrow$ Ala $\rightarrow$ Val $\rightarrow$ Leu $\rightarrow$ Gly

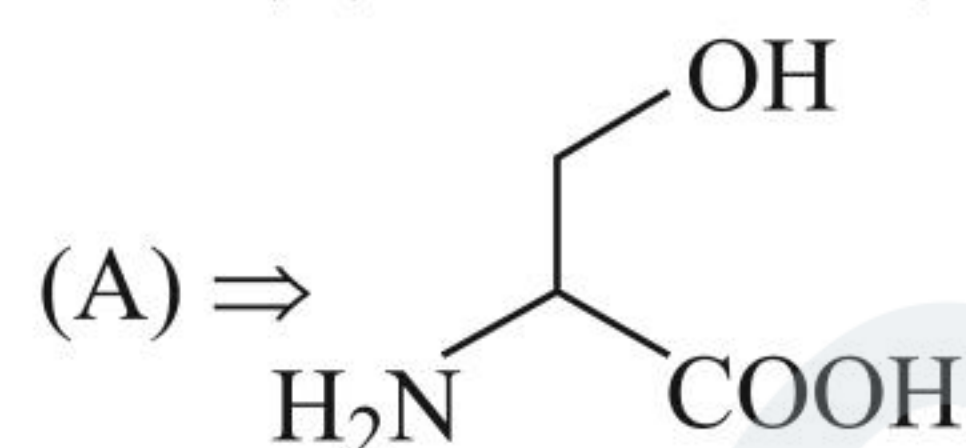
Answer of Q. No. 25. (d)

Paragraph 6

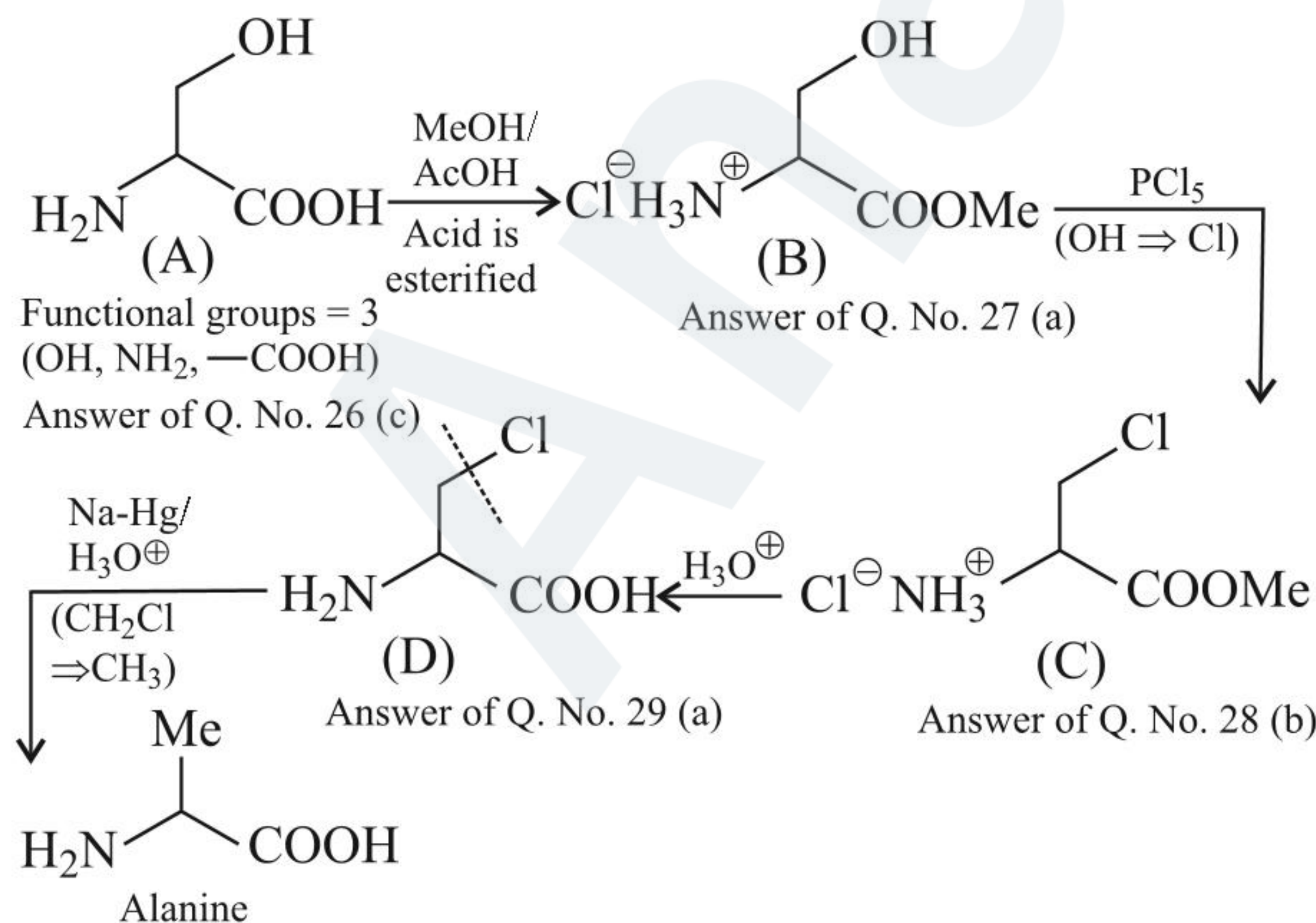
22. (3) 23. (1) 24. (2) 25. (1)

α -amino acid $\left(\begin{array}{c} \text{R} \\ | \\ \text{H}_2\text{N}-\text{C}-\text{COOH} \end{array} \right)$ type. Total C atoms in (A) = 3,

R = Me, but total O atoms in (A) = 3, So R = (CH₂OH).



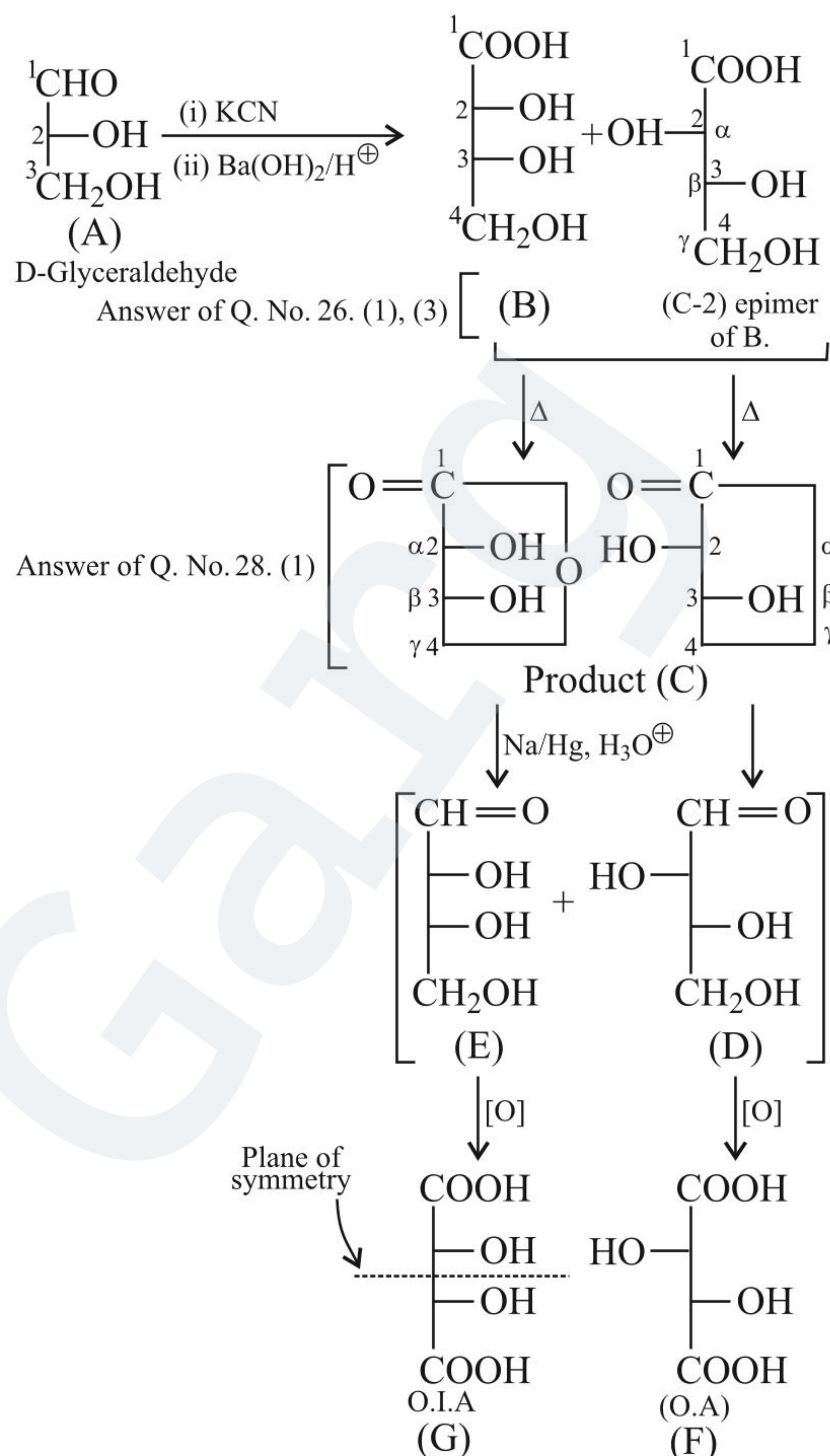
Reactions:



Paragraph 7

26. (1, 3) 27. (3) 28. (1) 29. (1)

The sequence from (A) to (D + E) is called Kiliani synthesis:



Answer of Q. No. 29. (1) Answer of Q. No. 29. (1)

Matrix Match Type

1. (a $\rightarrow$ p, q, r, s; b $\rightarrow$ p, q, r, s; c $\rightarrow$ u; d $\rightarrow$ q, r, s; e $\rightarrow$ q, r, s, u; f $\rightarrow$ q, r, s, t)

(a $\rightarrow$ p, q, r, s)

Glucose mutarotates because of hemiacetal; reduces Fehling's (q), Tollens (r), Benedict's (s) reagents. Schiff's reagent is a weak oxidising reagent and does not break the hemiacetalic linkage to free CHO group and does not react with glucose or fructose.

(b $\rightarrow$ p, q, r, s) Same explanation as in (a).

Fructose although ketone is a reducing sugar, because under the basic conditions of reagent (q), (r), and (s), fructose undergoes a rearrangement to form glucose and mannose (C-2 epimer of glucose).

(c $\rightarrow$ u)

Sucrose is a non-reducing sugar, so reagents q, r, s, t, do not react. It contains both α - and β -linkage, So it is hydrolysed by maltase.

(d $\rightarrow$ q, r, s)

Lactose is a reducing sugar, so reacts with reagents q, r, and s. It has β -linkage, hence it is not hydrolysed by maltase.

(e $\rightarrow$ q, r, s, u)

Maltose (α -linkage) is a reducing sugar; so reacts with reagents, q, r, s, and u.

(f $\rightarrow$ q, r, s, t)

It is a simple aldehyde, so reaction of aldehydic group occurs, i.e., reagents, q, r, s, and t react.

2. (a → t; b → p; c → s; d → q; e → r)

3. (a → r; b → s; c → p; d → q)

Anomers differ in the configuration at the acetal or hemiacetal C atom of sugar in its cyclic form. Anomer pairs are those in which there is difference of only the word α - or β -, the rest part is exactly the same.

4. (a → q; b → p; c → s; d → r)

(a → q) Definition of α -helix structure of protein.(b → p) Definition of β -pleated sheet structure of protein.(c → s) Definition of parallel β -pleated sheet structure of protein.(d → r) Definition of anti-parallel β -pleated sheet structure of protein.

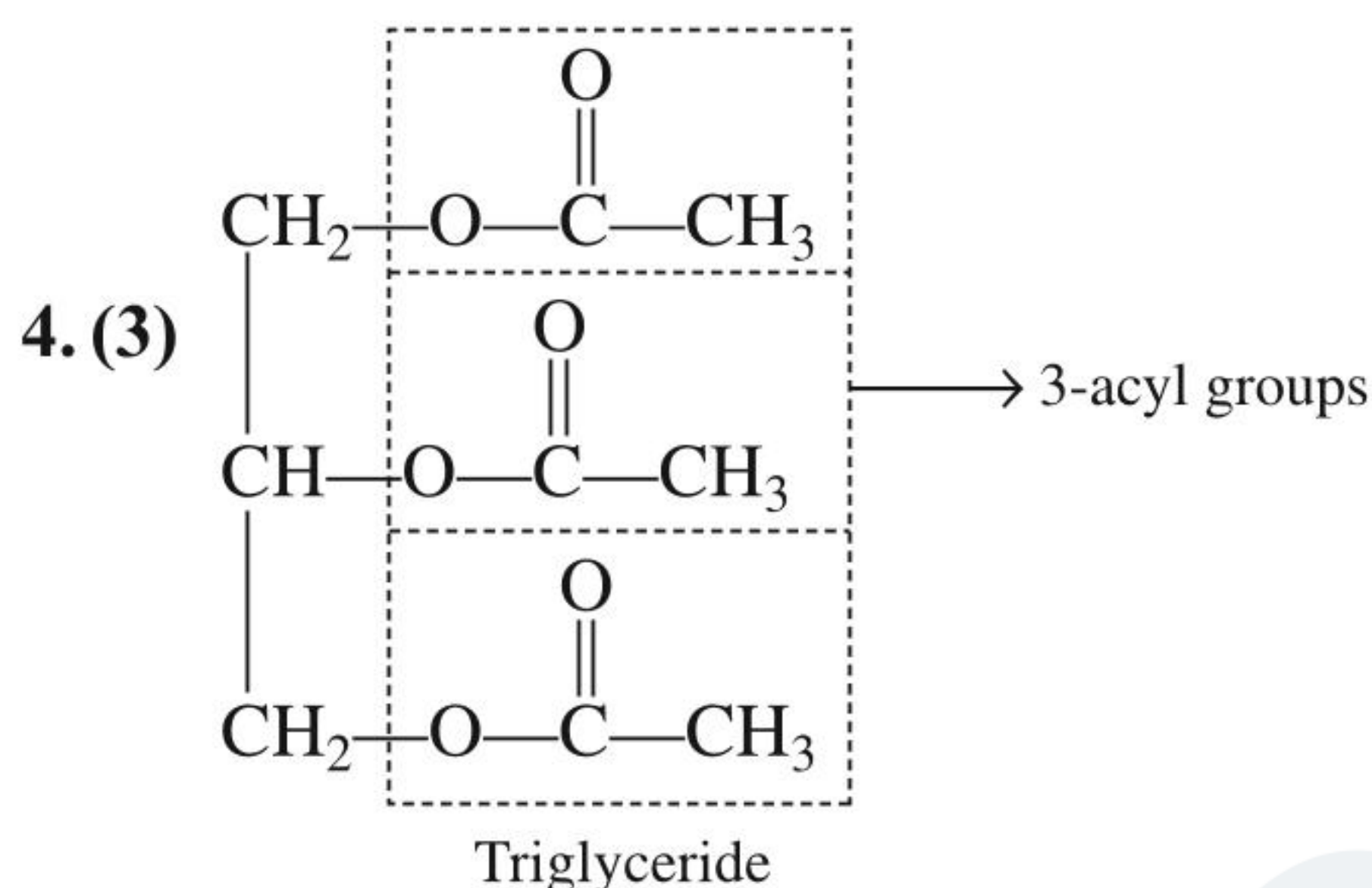
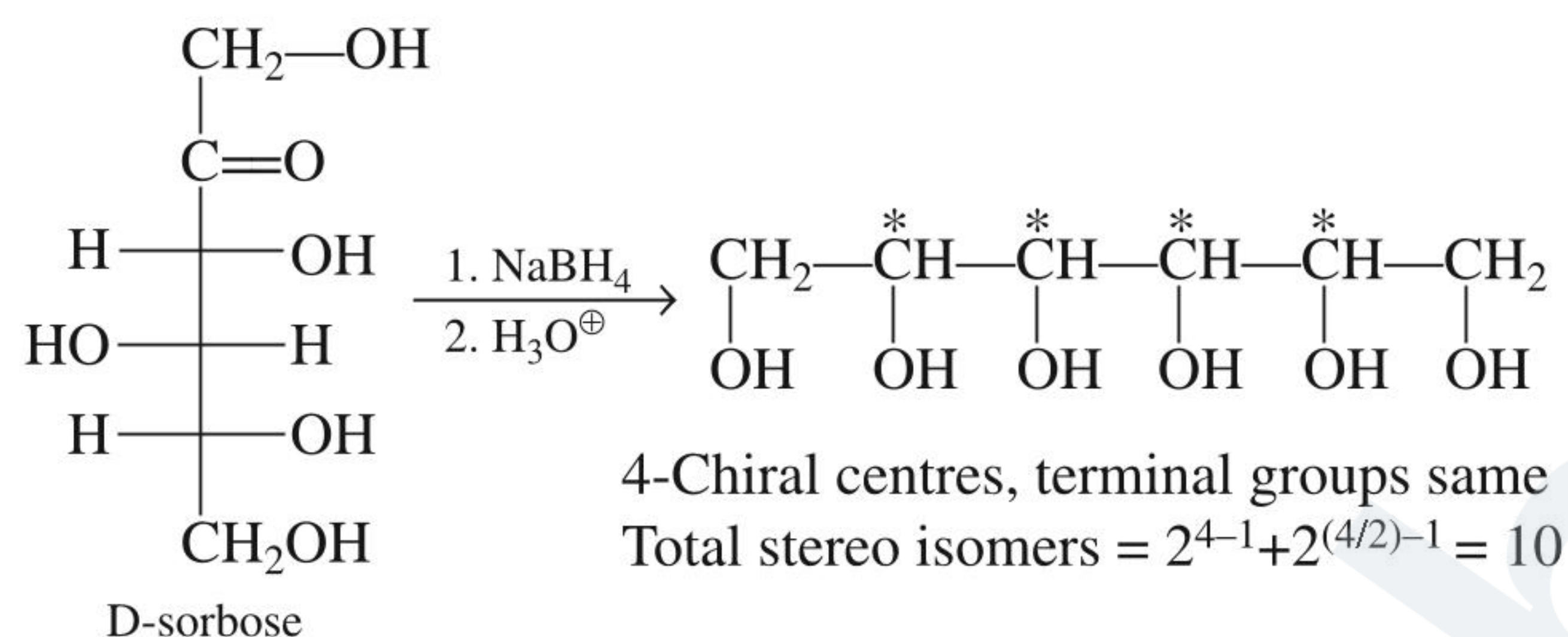
5. (a → iv → p; b → i → q; c → ii, v → r, t; d → iii → s)

Numerical Value Type

1. (5) a, b, c, d, e

2. (2) $-\text{COOH}$, NH_3^+

3. (10)



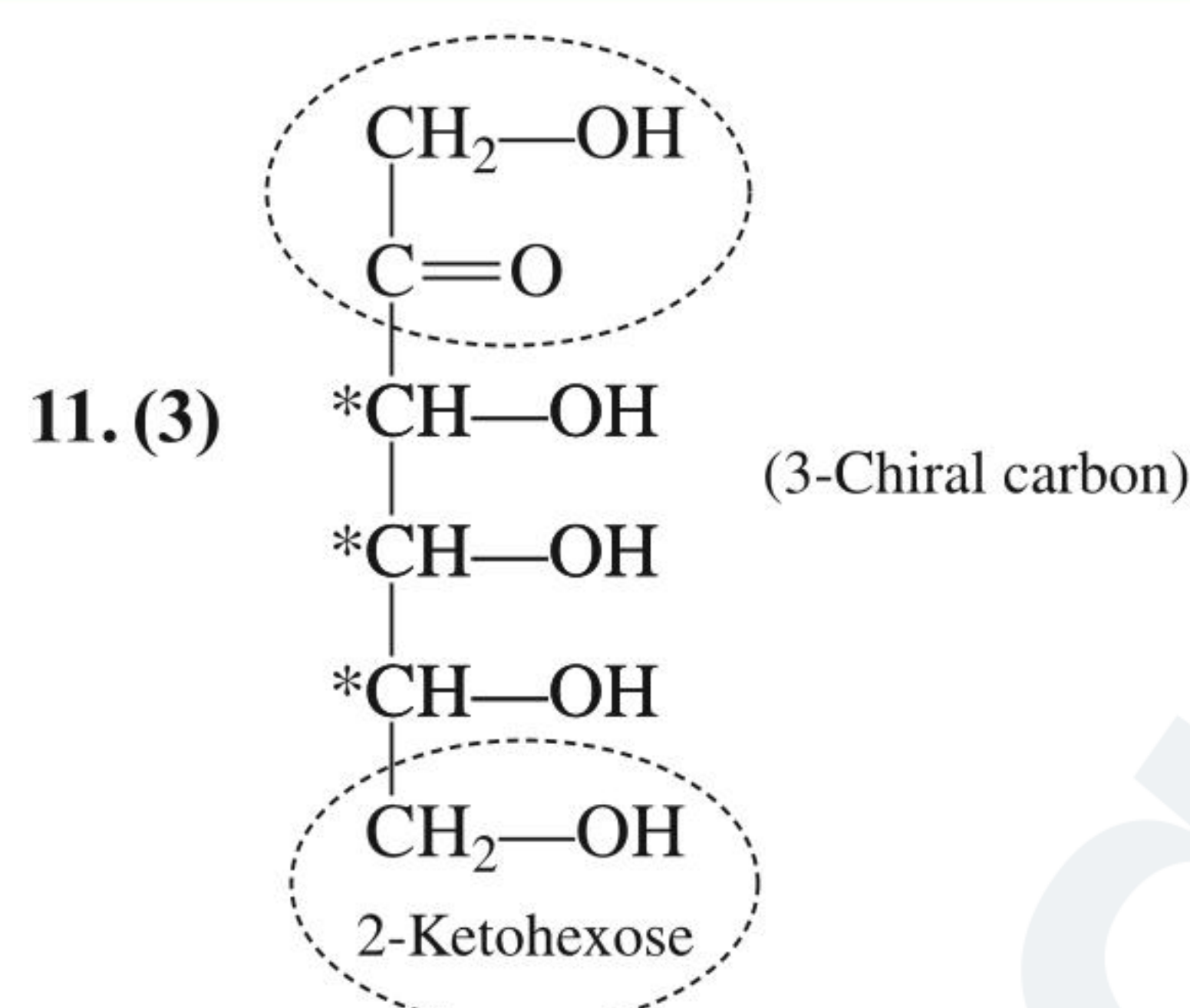
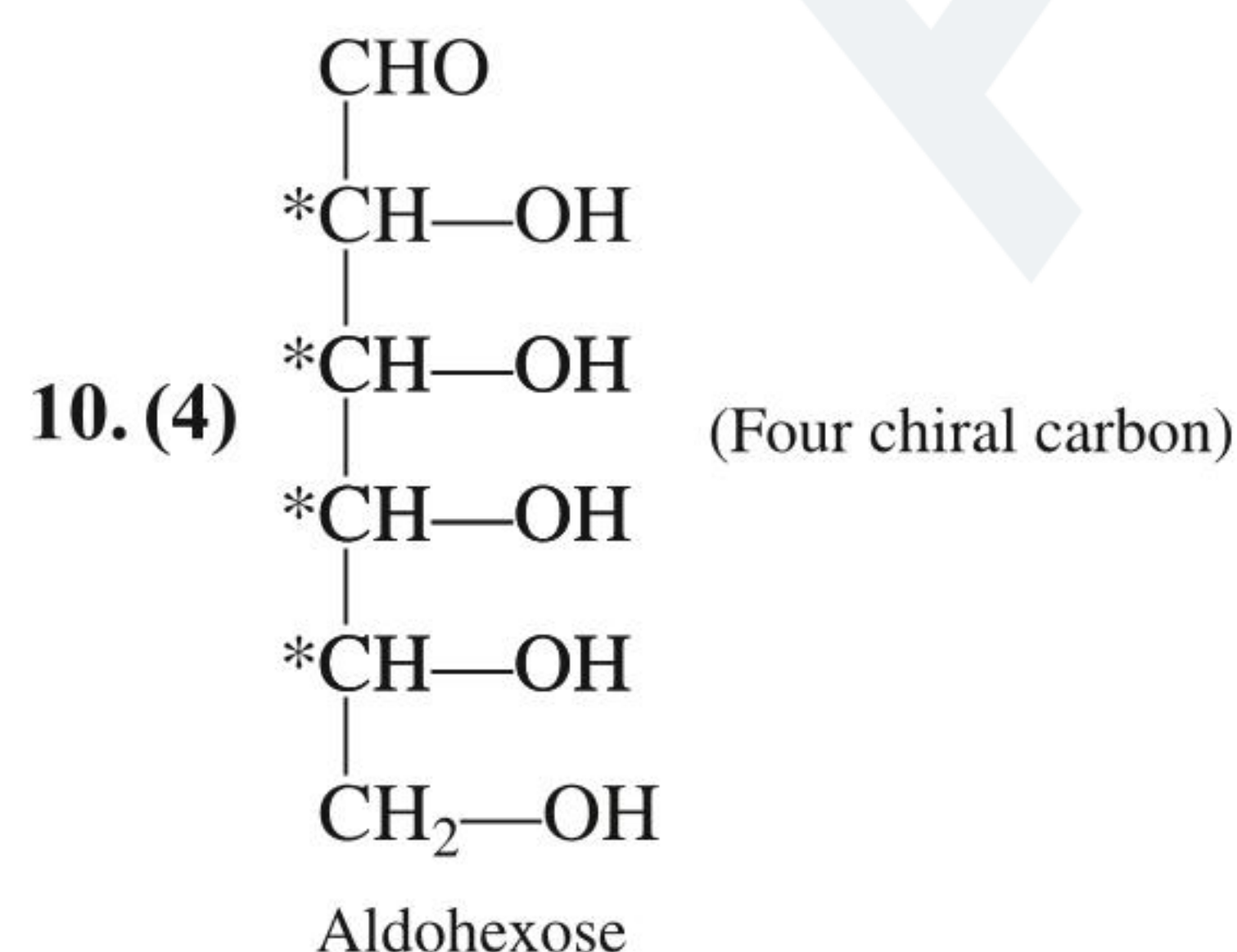
5. (3) In aqueous solution, glucose exist in three isomeric forms i.e., mannose, fructose and glucose.

6. (3) 3-moles of phenyl hydrazine reacts with one mole of glucose to form osazone.

7. (5) α -D-glucose have 5 chiral atoms.

8. (2) Only second carbon have different stereochemistry.

9. (4) Only C-4 have different stereochemistry.

12. (8) $n = 3$ (no. of stereocentres) as above with different terminal groups. No. of isomers = $2^3 = 8$ 13. (2) $-\text{COO}^-$, NH_2 14. (8) Each mole of the compound consume 5 moles of HIO_4 .
 $\therefore$ No of $\text{HIO}_4 = 16 \times 5 = 80$

$$X = \frac{80}{10} = 8$$

15. (2) No. of chiral center in 2-ketohexose = 4.

No. of isomers (when terminal groups are different) = $2^4 = 16$

$$X = \frac{16}{8} = 2$$

16. (4) No. of chiral center in an aldohexoses

OHC (CHOH) $_5$ CH_2OH ($n = 5$), when terminal groups are different. No. of isomers = $2^5 = 32$

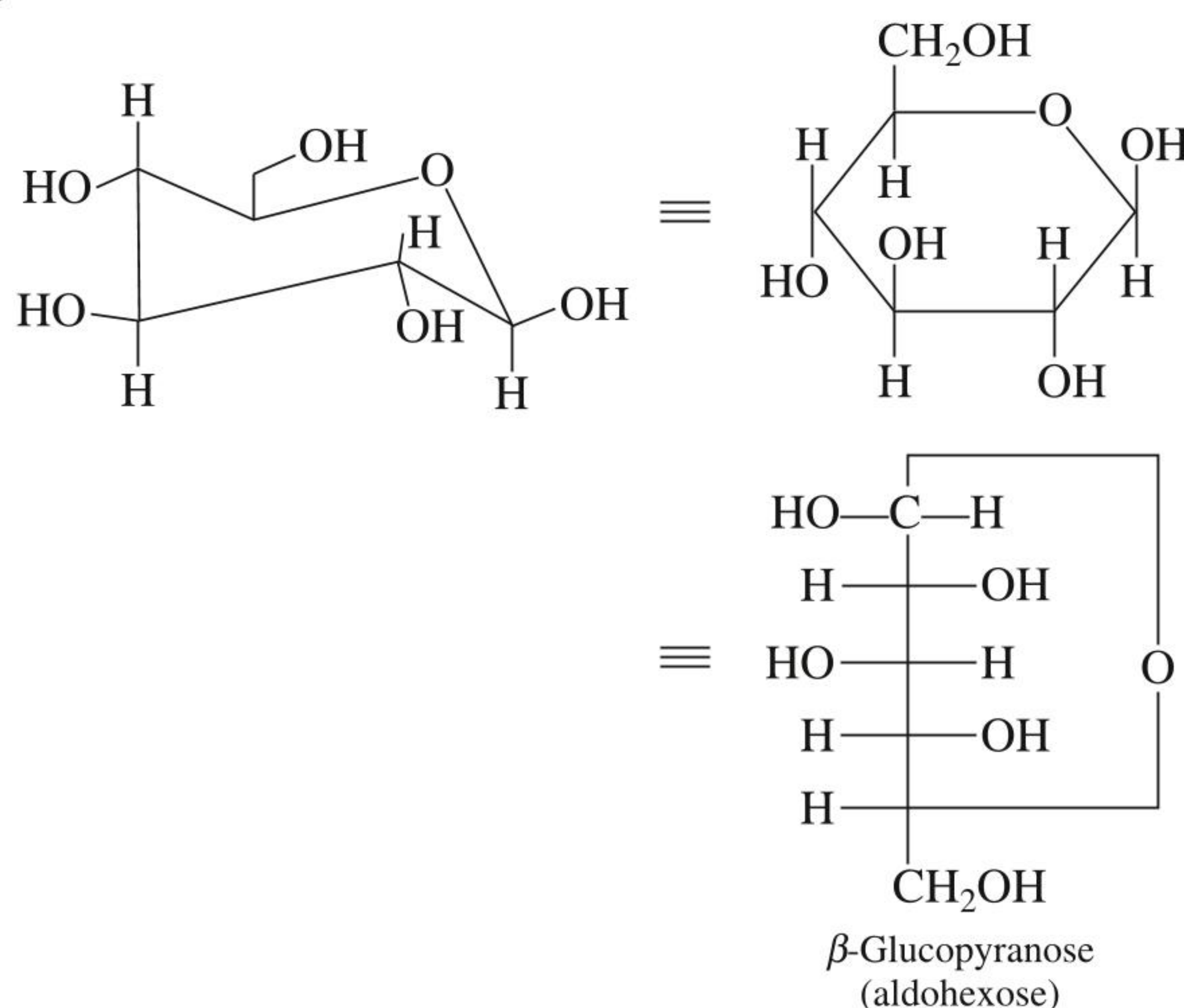
$$X = \frac{32}{8} = 4$$

17. (0) No chiral center. Hence zero stereo-isomer.

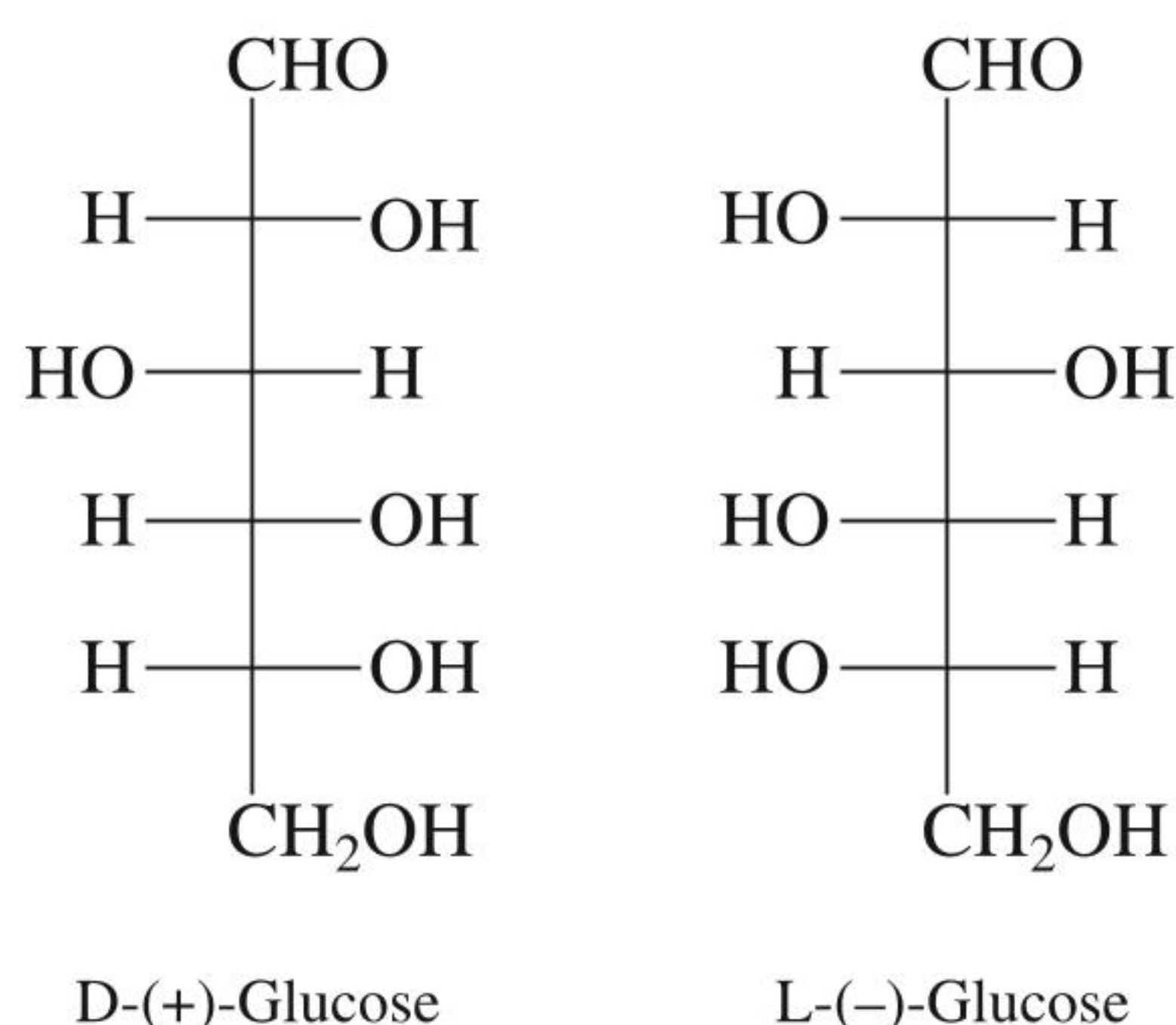
Archives**JEE Advanced****Single Correct Answer Type**

1. (4) Cellulose is the constituent of cell wall of plant cells.

2. (2)



3. (1)



4. (4) For the polypeptides the isoelectric point will be more than 7. It means that the given polypeptide is of basic nature so it must contain one or more than one amino group. The given polypeptide with following R_1 and R_2 are basic will remain protonated (cationic) at $pH = 7.0$

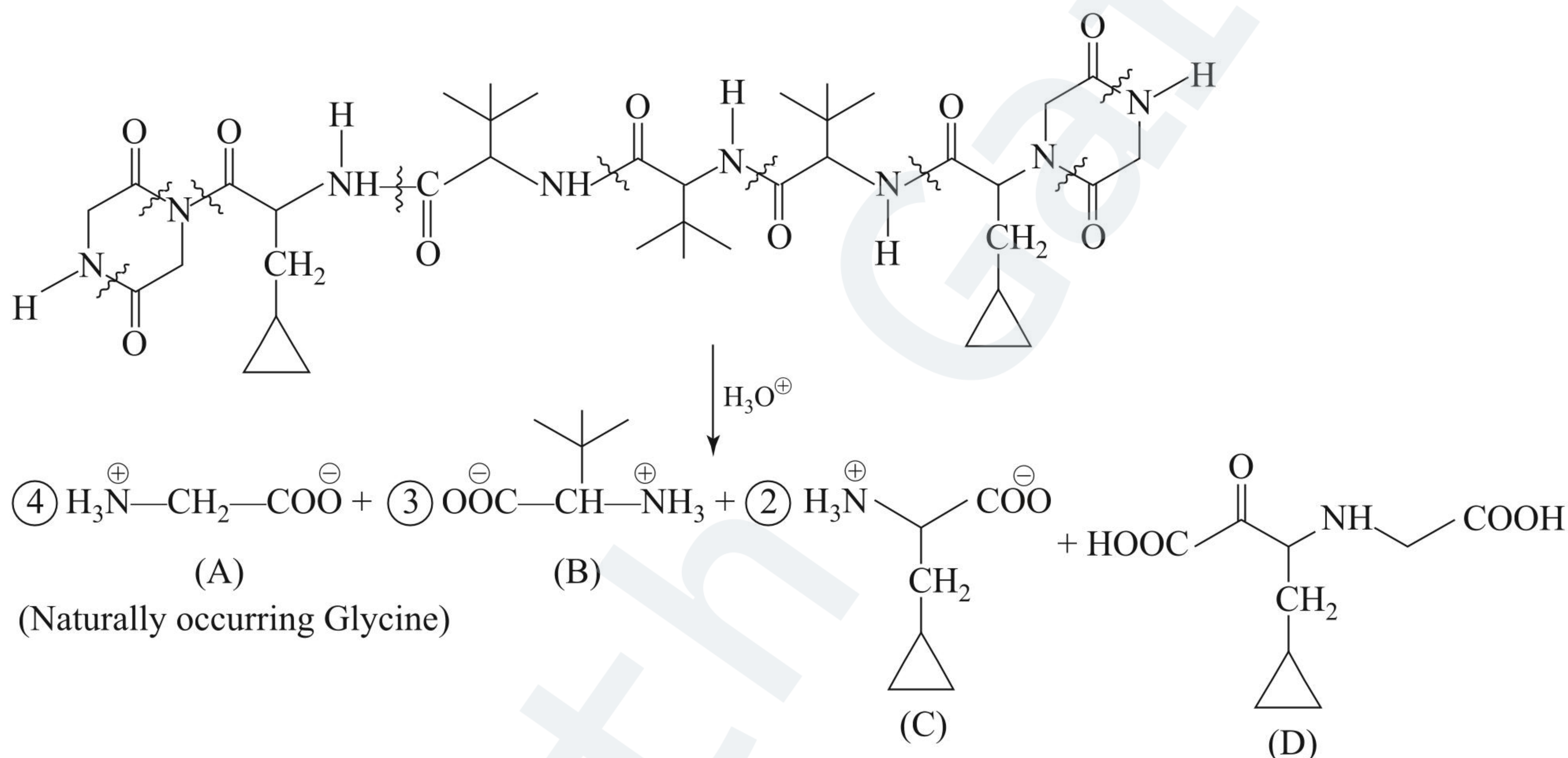
Poly-peptide	R_1	R_2	Inferences
IV	CH_2CONH_2	$(CH_2)_4NH_2$	One Amino group
VI	$(CH_2)_4NH_2$	$(CH_2)_4NH_2$	Two $-NH_2$ groups

VIII	CH_2OH	$(CH_2)_4NH_2$	One $-NH_2$ group
IX	$(CH_2)_4NH_2$	CH_3	One $-NH_2$ group

Polypeptide:

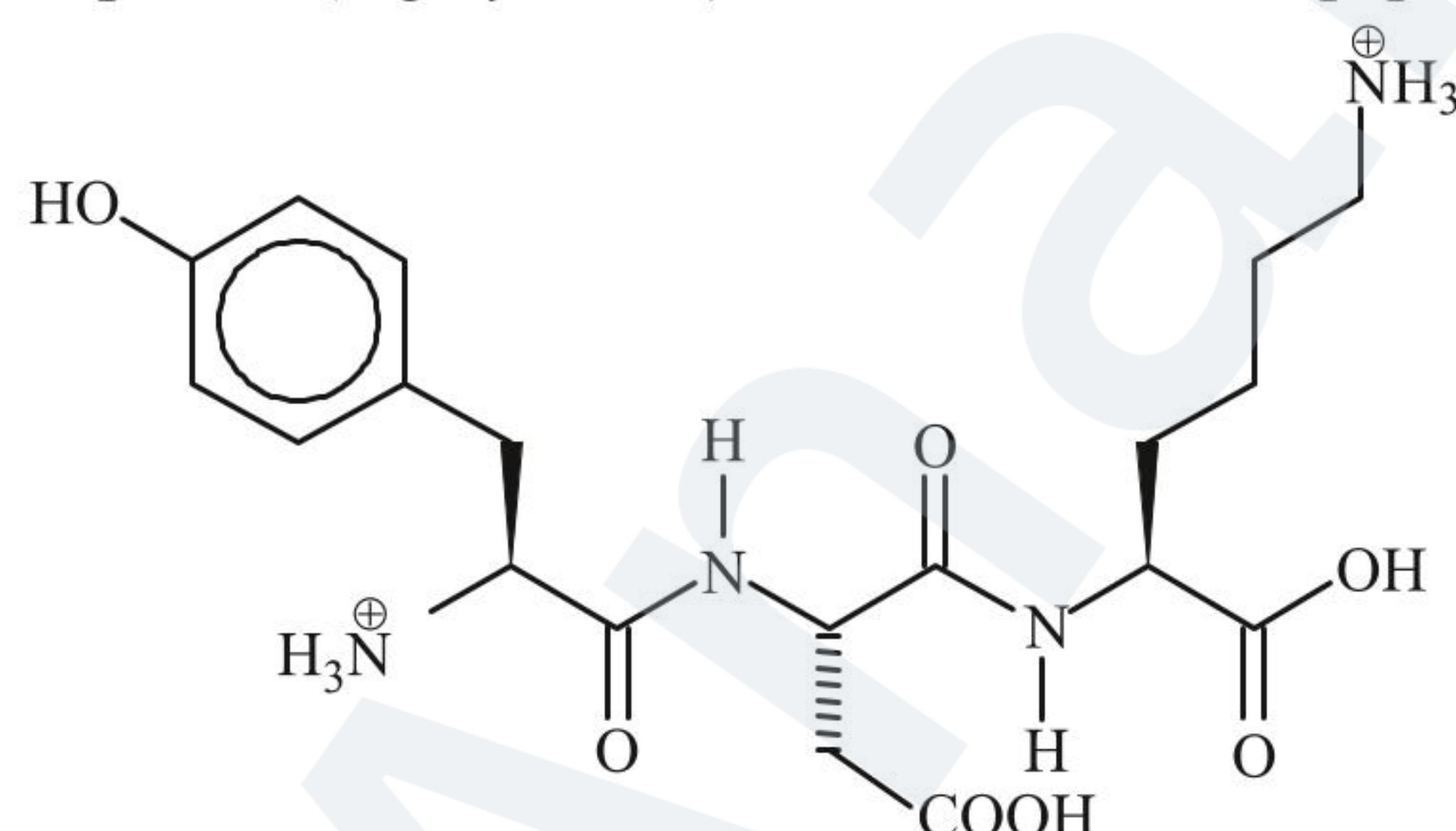
- I Contains both $(-H)$ atoms.
- II Contains one $(-H)$ and one $(-CH_3)$ group
- III Contains one $(-COOH)$ and $(-H)$ group
- V Contains both amide $(-CONH_2)$ group
- VII Contains one $(-COOH)$ and one amide $(-CONH_2)$ group.

5. (1)



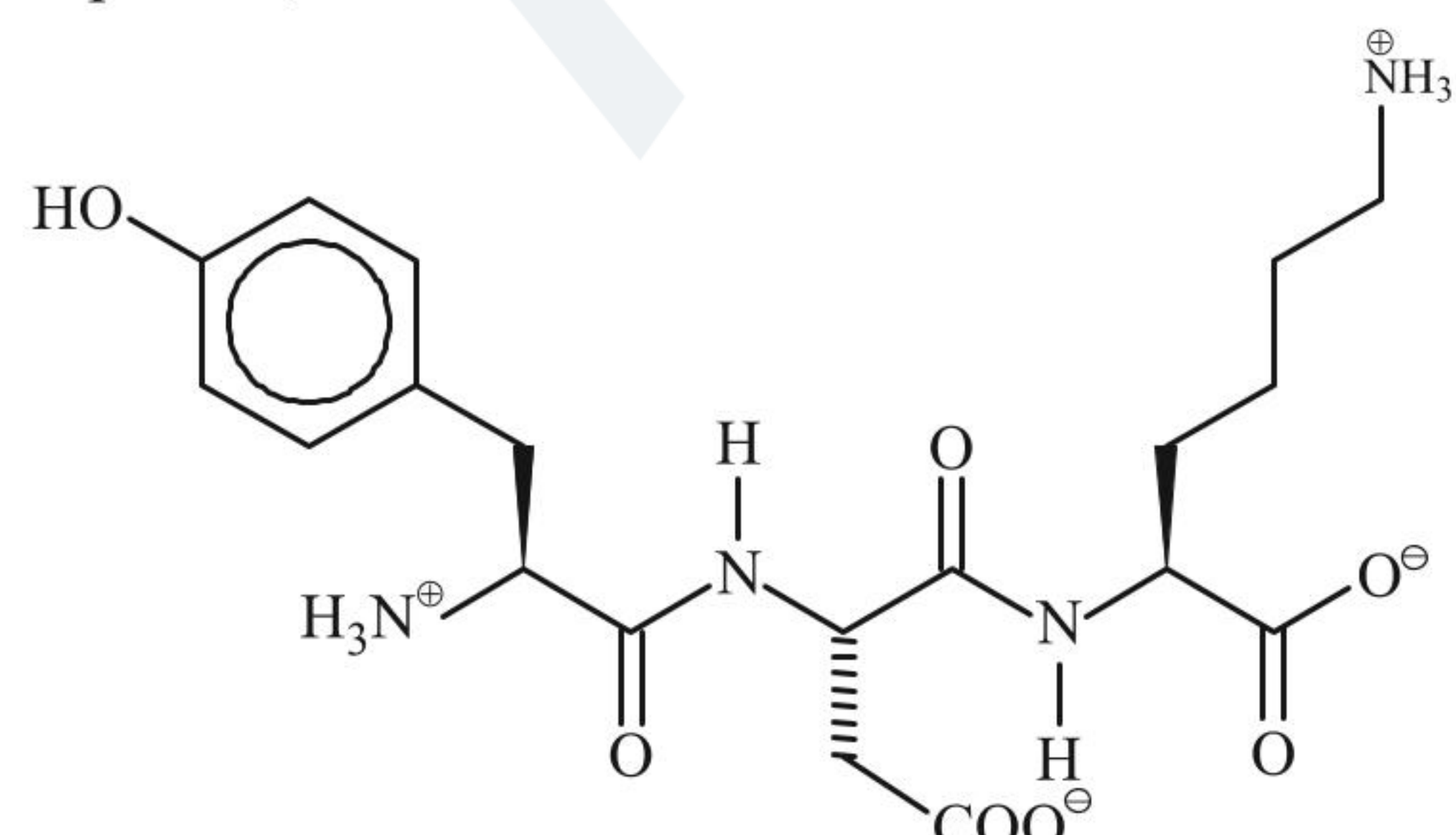
Structure (A) is glycine which is **only** naturally occurring amino acid. While (B), (C) and (D) are not the naturally occurring amino acids.

6. (5) At $pH = 2$ (highly acidic), the structure of the peptide is:



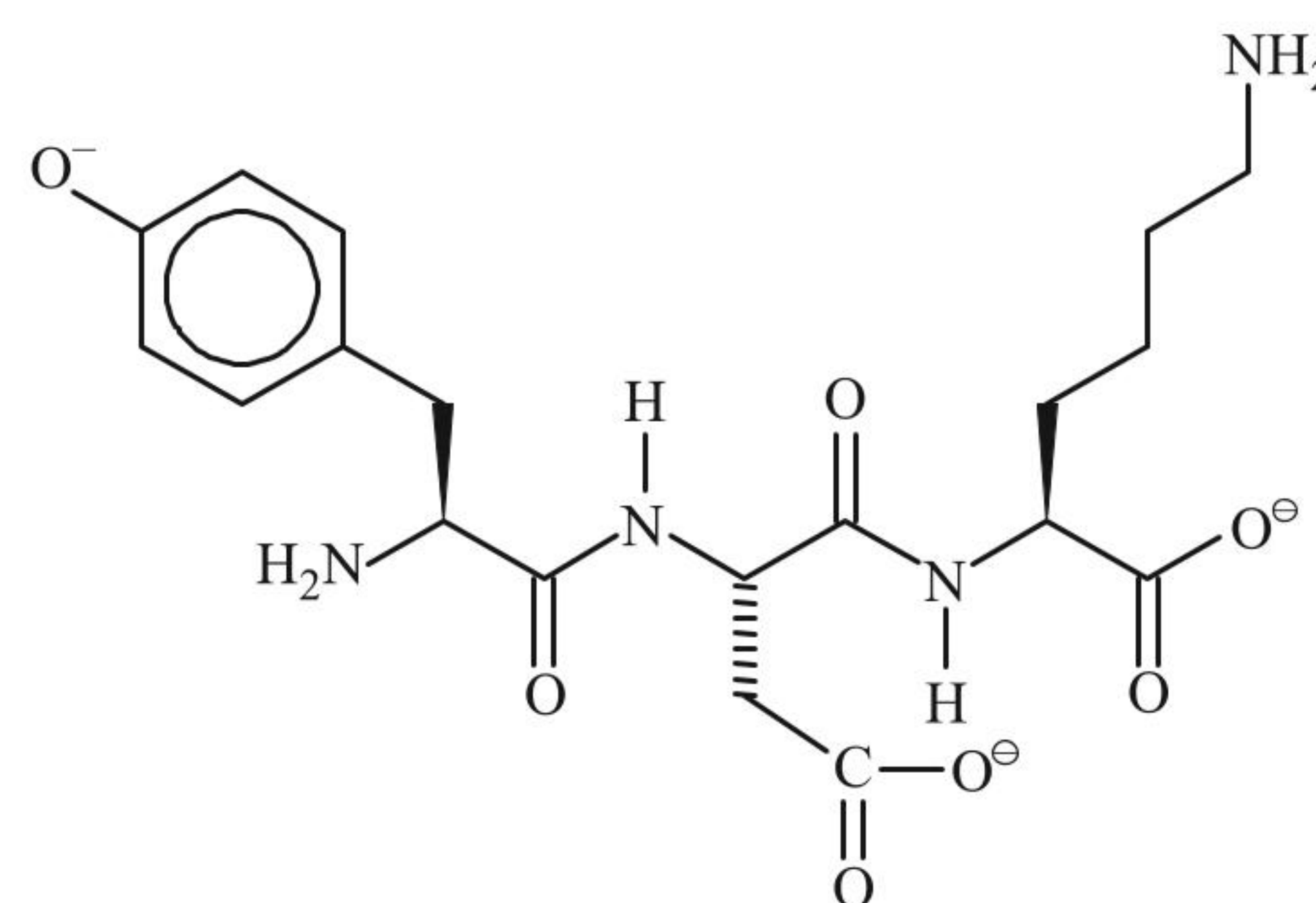
$$\text{So, } |Z_1| = 2$$

At $pH = 6$, it will exist as neutral or zwitter-ion structure is:



So, according to this condition, $|Z_2| = 0$

At $pH = 11$ (highly basic), the given peptide will exist as:



$$\text{So, } |Z_3| = |-3| = 3$$

$$|Z_1| + |Z_2| + |Z_3| = 2 + 0 + 3 = 5$$